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# APPENDIX A: Summary of the literature review on CMS

| Assumptions | Authors |
|---|---|
| **Assumptions related with machine data** | |
| Each machine type can perform one or more operations of different products | Niakan et al. (2016), Kia et al. (2014) |
| Each operation can be performed in different types of machines and possibly with different processing times. | Bayram & Sahin (2016), Dalfard (2013), Niakan et al. (2016), Kia et al. (2014) |
| Each machine has a limited capacity and several duplicates of the machines are allowed. Machine capacities are expressed in time units (e.g. h, days). | Hamedi et al. (2012), Bayram & Sahin (2016), Dalfard (2013), Niakan et al. (2016) |
| Time capacity of each machine is definite and fixed in all programming horizon. | Dalfard (2013) |
| Bounds and quantity of machines in each cell need to be specified in advance and they remain constant over time. | Bayram & Sahin (2016), Asgharpour & Javadian (2004) |
| All machines have the same dimension. Therefore any machine can be assigned to any location. However, only one machine can be assigned to a location. | Bayram & Sahin (2016) |
| Time of setting machinery and their failure probability are excluded. | Dalfard (2013), Bayram & Sahin (2016), Asgharpour & Javadian (2004), Sirovetnukul & Chutima (2010) |
| All machines are of rectangular shape | Dalfard (2013), Srinivas, Reddy, Ramji & Naveend (2014) |
| All machines are operated in the centre of that space | Srinivas et al. (2014) |
| The available surface for Machine layout is rectangular in shape | Srinivas, Reddy, Ramji & Naveen (2014) |
| Machines are not in the same size. | Allahyari & Azab (2015) |
| The sizes of all machines are equal with the dimensions of 1×1. | Golmohammadi, A. M., Tavakkoli-Moghaddam, Jolai & Golmohammadi, A. H. (2014) |
| The factory floor is divided into equal grids, and machines are assumed equal space in such a way that each machine just occupies one grid. | Hamedi et al. (2012) |
| Machines must be located within a given area. | Allahyari & Azab (2015) |
| In determining machine size and dimensions, the workspace required for operator usage and that needed to enforce between the different machines have been taken into account. | Allahyari & Azab (2015) |

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| A U-line comprises inexpensive and small non-automated machines | Sirovetnukul & Chutima (2010) |
| Breakdown cost for each machine type is known. | Sakhaii et al. (2016) |
| The failure rate for each machine type is known. | Sakhaii et al. (2016) |
| If a machine is purchased in a period, it must stay on the shop floor in the following periods. Removal of machines from the shop floor is not assumed. | Bayram & Sahin (2016) |
| Since in the first period, there is no machine available to be utilized, it will be required to purchase some machines to meet part demands. In the next periods, if the present time capacity of machines is not enough to satisfy the part demands, some other machines will be purchased and added to the current utilized machines. | Kia et al. (2014) |
| In each period when there is surplus capacity, idle machines can be removed from the cells and transferred to the machine depot, where the idle machines are kept in order to decrease the machine overhead costs and provide empty locations incells to accommodate required machines. Whenever it will be necessary to increase the processing time capacity of the system because of high demand volume, those machines can be returned to the cells. | Kia et al. (2014) |
| Cell reconfiguration involves different situations that are: (1) transferring of the existing machines between different locations of a same cell or different cells, (2) purchasing and adding new machines to cells, and (3) transferring machines between cells and the machine depot because of changing capacity requirements in successive periods. | Kia et al. (2014) |
| The relocation cost of each machine type is known. All machine types can be moved to the machine depot or any location in the cells. This cost is paid for several situations: (1) to trans-fer and install a new purchased machine, (2) to relocate a machine between a cell and the machine depot, and (3) to relocate a machine between two different locations of a same cell or different cells. For the sake of simplicity, it is assumed that the unit cost of relocating a machine is the same for all three situations. | Kia et al. (2014) |
| Replacement cost of machines consists of installation and un-installation costs. When a machine is moved from one location to another, both installation and un-installation costs are incurred. Regardless of the purchase period, | Bayram & Sahin (2016) |

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| installation cost is incurred for every new machine. Both installation and un-installation costs are expressed in terms of money per each relocation. | |
| The machine relocation cost during the periods is constant and known for a PER machine. This cost includes opening, transferring and resetting the machine. | Golmohammadi et al. (2014) |
| Cost of investment or purchase of any machine is independent of the work load allocated to it. | Dalfard (2013) |
| The time value of money is not considered in the CMS model | Asgharpour & Javadian (2004) |
| **Assumptions related with part data** | |
| Demand for each product type is varying in subsequent periods and the demand is known deterministically prior to the design. | Hamedi et al. (2012), Bayram & Sahin (2016), Dalfard (2013) |
| Demand must be satisfied in a given period hence backorders are not allowed. | Golmohammadi et al. (2014), Bayram & Sahin (2016) |
| Demand for each product is expressed in number units. | Hamedi et al. (2012), Bayram & Sahin (2016), Dalfard (2013), Golmohammadi et al. (2014) |
| The operating times for all part type operations on different machine types are known. | Dalfard (2013), Asgharpour & Javadian (2004) |
| The demand density function for each part type in each period is known. | Dalfard (2013), Asgharpour & Javadian (2004) |
| Processing capabilities are 100% reliable (i.e. no rework / scrap). | Dalfard (2013), Asgharpour & Javadian (2004) |
| No inventory is considered. | Golmohammadi et al. (2014), Dalfard (2013), |
| No queuing in production is allowed. | Dalfard (2013), Asgharpour & Javadian (2004) |
| Batch size is constant for all products and all periods. | Dalfard (2013), Asgharpour & Javadian (2004) |
| There is an operation sequence for each product. | Bayram & Sahin (2016), Dalfard (2013), Deep & Singh (2015), Kia et al. (2014), Sirovetnukul & Chutima (2010), Niakan et al. (2016) |
| In case of subcontracting a certain part, all the operations of that part are made by one supplier; however, different parts can be made by different suppliers. | Mohammadi & Forghani (2016) |
| The processing routings of parts and the operation sequences in each routing are pre-specified. | Mohammadi & Forghani (2016) |

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| Only one routing must be selected for processing each part type. | Mohammadi & Forghani (2016) |
| Demand for each period is uncertain. | Mohammadi & Forghani (2016), Niakan et al. (2016) |
| **Assumptions related with material movement** | |
| The cost of carrying items between two locations is proportional to the number of carried products. | Niakan et al. (2016), Bayram & Sahin (2016) |
| Both inter-cell and intra-cell material handling costs are linearly proportional to the distance between the locations of the machines. | Kia et al. (2014), Golmohammadi et al. (2014) |
| Parts move inside and outside the cells. Cost of cumulative inter-cell movement is more than that of intra-cell movement. | Dalfard (2013) |
| The predetermined places (candidate places) are adopted with considering movement inside the cells. Number of the places indicates the maximum number of permissible machinery inside that cell. Dimensions of the cells are not necessarily equal. | Dalfard (2013) |
| Parts are moved between and inside of cells in batches. The inter-call and intra-cell material handling cost per batch between and inside of cells is known and constant (independent of quantity of cells) | Dalfard (2013), Golmohammadi et al. (2014) |
| Inter-cell and intra-cell handling costs are constant for all moves regardless of the distance traveled. | Asgharpour & Javadian (2004) |
| For each part type, the unit inter- and intra-cell material handling costs per unit distance as well as the unit production and outsourcing costs are known in advance. | Mohammadi & Forghani (2016) |
| Material handling devices moving the part between machines are assumed to carry only one part at a time | Allahyari & Azab (2015), Kia et al. (2014) |
| The distance between two machines is calculated through a rectilinear distance. | Kia et al. (2014), Golmohammadi et al. (2014) |
| There is no physical partitioning between cells and a location can be assigned to different cells in different periods. | Bayram & Sahin (2016) |
| **Assumptions related with operators** | |
| Trained homogeneous skilled workers have the same efficiency and multi- functional skills and are able to operate any processes or machines. They walk in a circle inside the U-line (also called the zone constraint – machines allocated to each worker must be adjacently located within a loop) | Sirovetnukul & Chutima (2010) |
| A worker is assigned to one station (or one loop) only | Sirovetnukul & Chutima (2010) |
| A task cannot be split between two or more workers | Sirovetnukul & Chutima |

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| | (2010) |
| Each worker is able to produce any product in any cycle. Consequently, job sequence is regardless at any period | Sirovetnukul & Chutima (2010) |
| Learning effect has no consideration since it is assumed that worker performance runs into steady state already | Sirovetnukul & Chutima (2010) |
| The hiring cost of each operator type is known. | Sakhaii et al. (2016) |
| The required time for relocation and operator training is assumed to be zero. | Sakhaii et al. (2016) |
| If an operator is able to work with specific machine or is trained to work with it, this learning effect will be considered in succeeding periods. | Sakhaii et al. (2016) |
| The minimum and maximum numbers of workers, which can be placed in each cell, are predetermined. | Hamedi et al. (2012) |
| Only multi-skilled workers, who can handle more than one machine, are considered. | Hamedi et al. (2012) |
| Each worker has the different level of job skills (multi-level flexibility). | Hamedi et al. (2012) |
| Workers have a different level of proficiency at performing their assigned tasks (heterogeneous worker flexibility). | Hamedi et al. (2012) |
| The maximum number of virtual cells, which each worker can be assigned, is predefined. | Hamedi et al. (2012) |
| The total capacity of workforces can be changed by hiring and firing of workers. | Hamedi et al. (2012) |
| The cross-training, hiring, and firing costs can be different between workers. | Hamedi et al. (2012) |
| The cross-training cost will be equal to zero if the worker is currently capable of performing the function and a value of one if the worker is incapable of being cross-trained to perform the function. | Hamedi et al. (2012) |
| **Assumptions related with CMS design** | |
| The number of cells used must be specified in advance and it remains constant over time. | Golmohammadi et al. (2014), Asgharpour & Javadian (2004) |
| Machine relocation from one cell to another is performed between periods and it requires zero time. | Asgharpour & Javadian (2004) |
| The machine relocation cost of each machine type is known and it is independent of where machines are actually being relocation. | Dalfard (2013), Asgharpour & Javadian (2004) |
| The maximum number of cells and the minimum and the maximum number of machines in cells are assumed to be known in advance. | Niakan et al. (2016), Bayram & Sahin (2016) |

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| Positions and shapes of the cells are not predetermined. | Bayram & Sahin (2016) |
| Splitting of lots is allowed. Namely, an operation of a product can be split between two machines of same or different types, in a given period. | Bayram & Sahin (2016) |
| Cell's dimensions and orientation are predetermined | Allahyari & Azab (2015) |

| Input parameters | Authors |
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| **Part data** | |
| Production volume/demand quantity | Sakhaii et al. (2016), Mohammadi & Forghani (2016), Shafigh et al. (2015), Bayram & Sahin (2016), Mahdavi, Teymourian et al. (2013), Rafiee et al. (2011), Raminfar et al. (2013), Han, Wang & Lv (2014), Deep & Singh (2015), Dalfard (2013), Rafiei & Ghodsi (2013) |
| Lower and upper bound for number of parts in a cell | Mahdavi, Teymourian et al. (2013) |
| Transfer batch size/bundle size | Mahdavi, Teymourian et al. (2013), Dalfard (2013), Niakan et al. (2016), Rafiei & Ghodsi (2013) |
| Precedence constraints/ operation sequence | Sirovetnukul & Chutima (2010) |
| Number of planning periods in the planning horizon | Sakhaii et al. (2016), Niakan et al. (2016), Rafiei & Ghodsi (2013), Shafigh et al. (2015) |
| Length of planning period | Shafigh et al. (2015) |
| Mean arrival rate of parts | Esmailnezhad, Fattahi & Kheirkhah (2015) |
| Number of parts/product types to be produced | Sakhaii et al. (2016), Niakan et al. (2016), Bayram & Sahin (2016) |
| Total available time for part types | Hamedi et al. (2012) |
| Processing time of part operation on specified machine | Sakhaii et al. (2016), Mohammadi & Forghani (2016), Rafiee et al. (2011), Raminfar et al. (2013), Han et al. (2014), Deep & Singh (2015), Dalfard (2013), Bayram & Sahin (2016), Niakan et al. (2016), Sirovetnukul & Chutima (2010) |
| Number of operations for a part | Bayram & Sahin (2016), Niakan et al. (2016), Sirovetnukul & Chutima (2010) |
| **Machine data** | |
| Lower and upper bound for number of machines in a cell | Mahdavi, Teymourian et al. (2013), Chang, Wu, T. & Wu, C. (2013), Rafiee et al. (2011), Hamedi et al. (2012), Raminfar et al. (2013), Deep & Singh (2015) |
| Machine capacity in time units | Mohammadi & Forghani (2016), Sakhaii et al. (2016), Rafiee et al. (2011), Raminfar et al. (2013), Deep & Singh (2015), Han et al. (2014), Dalfard (2013), Rafiei & Ghodsi (2013), Bayram & Sahin (2016), Niakan et al. (2016) |
| Number of machines | Murray et al. (2012), Han et al. (2014), Chang, Wu, T. |

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| | & Wu, C. (2013) |
| Mean service rate of machines | Esmailnezhad et al. (2015) |
| Mean time between failures | Esmailnezhad et al. (2015) |
| Mean time between repairs | Esmailnezhad et al. (2015) |
| Breakdown rate of one type machine in processing a part type | Rafiee et al. (2011) |
| Number of machine types | Bayram & Sahin (2016), Niakan et al. (2016) |
| **Dimensional data** | |
| Width of machine | Mohammadi & Forghani (2016) |
| Length of machine | Mohammadi & Forghani (2016) |
| Aisle distance between machines in a same cell | Murray et al. (2012) |
| Aisle distance between cells | Murray et al. (2012), Mohammadi & Forghani (2016) |
| Horizontal and vertical dimensions of plant floor | Allahyari & Azab (2015) |
| Number of candidate locations to be a cell/in plant floor | Sakhaii et al. (2016), Bayram & Sahin (2016) |
| Travelling distances between cells | Mahdavi, Teymourian et al. (2013) |
| Distance between two candidate cell locations | Sakhaii et al. (2016), Bayram & Sahin (2016), Dalfard (2013) |
| Maximum number of machines permissible in a cell | Han et al. (2014), Bayram & Sahin (2016), Mohammadi & Forghani (2016) |
| Minimum number of machines allowable in a cell | Niakan et al. (2016), Bayram & Sahin (2016), Han et al. (2014) |
| Maximum number of cells | Niakan et al. (2016), Bayram & Sahin (2016), Rafiei & Ghodsi (2013) |
| **Operator related data** | |
| Number of available operators | Sakhaii et al. (2016) |
| Training cost for individual operators to operate with different individual machines | Sakhaii et al. (2016) |
| Hiring cost per operator | Sakhaii et al. (2016) |
| Maximum and minimum number of workers allowed per cell | Hamedi et al. (2012) |
| Available time for operators | Rafiei & Ghodsi (2013) |
| **Cost related data** | |
| Cost of backtracking and forward movement of unit | Mahdavi, Teymourian et al. (2013) |

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| distance | |
| Incremental cost of subcontracting | Mohammadi & Forghani (2016) |
| Production cost of part using defined route | Mohammadi & Forghani (2016) |
| Intra-cell material handling cost for transporting specific part from specified machines to another | Mohammadi & Forghani (2016) |
| Inter-cell material handling cost for transporting specific part from specified machines to another | Mohammadi & Forghani (2016) |
| Unit cost of in-house production | Shafigh et al. (2015) |
| Unit cost of subcontracting | Rafiee et al. (2011), Deep & Singh (2015), Shafigh et al. (2015) |
| Unit inventory holding cost | Han et al. (2014), Sakhaii et al. (2016), Shafigh et al. (2015) |
| Unit backorder cost | Sakhaii et al. (2016), Shafigh et al. (2015) |
| Material handling cost per unit distance for one unit of product | Bayram & Sahin (2016), Shafigh et al. (2015) |
| Relocation cost per unit distance for a machine | Shafigh et al. (2015) |
| Setup cost for processing a sub-lot of product | Shafigh et al. (2015) |
| Inter-cell part trip unit cost per batch | Sakhaii et al. (2016), Rafiee et al. (2011), Raminfar et al. (2013), Han et al. (2014), Deep & Singh (2015), Rafiei & Ghodsi (2013) |
| Intra-cell part trip unit cost per batch | Sakhaii et al. (2016), Rafiee et al. (2011), Raminfar et al. (2013), Han et al. (2014), Deep & Singh (2015), Rafiei & Ghodsi (2013) |
| Replacement cost of one defective item | Rafiee et al. (2011) |
| Procurement cost of individual machine types | Rafiee et al. (2011), Bayram & Sahin (2016), Deep & Singh (2015) |
| Installation cost of one type machine | Rafiee et al. (2011), Bayram & Sahin (2016), Deep & Singh (2015) |
| Removing cost of one type machine | Rafiee et al. (2011), Bayram & Sahin (2016), Deep & Singh (2015) |
| Operational cost per hour of one type machine | Raminfar et al. (2013), Han et al. (2014), Deep & Singh (2015) |
| Cost per time unit of corrective repair | Rafiee et al. (2011) |
| Total cost of preventive | Rafiee et al. (2011) |

| maintenance for one type machine | |
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| Hiring cost per worker | Hamedi et al. (2012) |
| Firing cost per worker | Hamedi et al. (2012) |
| Overhead cost per machine type in each period | Bayram & Sahin (2016), Deep & Singh (2015), Niakan et al. (2016) |
| Setup cost of route for part in period | Han et al. (2014) |
| Salary cost per worker | Niakan et al. (2016) |

| Objective functions | Authors |
|---|---|
| **Cost terms** | |
| Inter-cell and Intra-cell movement cost | Murray et al. (2012), Sakhaii et al. (2016), Rafiee et al. (2011), Kia et al. (2014), Golmohammadi et al. (2014), Shafigh et al. (2015), Deep & Singh (2015), Dalfard (2013), Mohammadi & Forghani (2016), Niakan et al. (2016), Rafiei & Ghodsi (2013), Han et al. (2014), Mahdavi, Teymourian et al. (2013), Allahyari & Azab (2015), Raminfar et al. (2013) |
| Production cost | Shafigh et al. (2015), Mohammadi & Forghani (2016) |
| Subcontracting cost | Shafigh et al. (2015), Mohammadi & Forghani (2016), Rafiee et al. (2011), Deep & Singh (2015) |
| Machine relocation cost | Mohammadi & Forghani (2016), Shafigh et al. (2015), Sakhaii et al. (2016), Bayram & Sahin (2016), Niakan et al. (2016), Kia et al. (2014), Golmohammadi et al. (2014), Dalfard (2013), Rafiei & Ghodsi (2013) |
| Inventory holding cost | Shafigh et al. (2015), Sakhaii et al. (2016), Rafiee et al. (2011), Han et al. (2014) |
| Machine setup cost | Shafigh et al. (2015), Rafiee et al. (2011) |
| Machine breakdown cost | Chung, Wu & Chang (2011), Sakhaii et al. (2016) |
| Operator hiring cost | Sakhaii et al. (2016), Hamedi et al. (2012) |
| Operator training cost | Sakhaii et al. (2016), Hamedi et al. (2012) |
| Machine procurement cost | Sakhaii et al. (2016), Rafiee et al. (2011), Dalfard (2013), Bayram & Sahin (2016), Kia et al. (2014), Deep & Singh (2015), Niakan et al. (2016), Rafiei & Ghodsi (2013) |
| Machine operational cost | Bayram & Sahin (2016), Kia et al. (2014), Sakhaii et al. (2016), Rafiee et al. (2011), Dalfard (2013), Deep & Singh (2015), Han et al. (2014) |
| Corrective repair cost | Rafiee et al. (2011), Sakhaii et al. (2016) |
| Preventive maintenance cost | Rafiee et al. (2011), Sakhaii et al. (2016) |
| Operator firing cost | Hamedi et al. (2012) |
| Machine installation cost | Bayram & Sahin (2016) |
| Machine un-installation | Bayram & Sahin (2016) |

| | |
|---|---|
| cost | |
| Machine overhead cost | Bayram & Sahin (2016), Niakan et al. (2016) |
| Process routes setup cost | Han et al. (2014) |
| Salary cost | Niakan et al. (2016) |
| Revenue from machine selling | Niakan et al. (2016), Rafiei & Ghodsi (2013) |
| Overtime cost | Rafiei & Ghodsi (2013) |
| Cost of moving operators from one cell to another | Rafiei & Ghodsi (2013) |
| **Other** | |
| Minimize number of exceptional elements regarding the production volume of each part | Mahdavi, Teymourian et al. (2013) |
| Minimize area consumed by cells | Murray et al. (2012) |
| Minimize deviation of operation times of workers | Sirovetnukul & Chutima (2010) |
| Minimize walking time | Sirovetnukul & Chutima (2010) |
| Minimize total inter-cellular movement distance | Chang, Wu, T. & Wu, C. (2013) |
| Maximize average effective arrival rate | Esmailnezhad et al. (2015) |
| Minimize total number of voids and exceptional elements in part-machine-worker matrix | Mahdavi, Aalaei et al. (2012) |

| Constraints | Authors |
|---|---|
| Each operation of the part is assigned to one cell in each period | Nouri (2016), Deep & Singh (2015), Mohammadi & Forghani (2014), Egilmez, & Suer (2011), Deljoo et al. (2010) |
| Internal part operation processing is limited to available machine capacity | Nouri (2016), Deep & Singh (2015), Mohammadi & Forghani (2014), Dalfard (2013), Hamedi et al. (2012), Rezazadeh, Mahini, & Zarei (2011), Deljoo et al. (2010) |
| The required number of each machine type and worker type in each cell with machine or worker duplication is determined | Nouri (2016) |
| The cell size lies within the upper and lower limits in terms of the number of machines | Nouri (2016), Bayram & Sahin (2016), Khannan et al. (2016), |

| | |
|---|---|
| | Deep & Singh (2015), Mohammadi & Forghani (2014), Dalfard (2013), Mahdhavi, Aalaei et al. (2012), Deljoo et al. (2010) |
| Ensure that the number of machines/workers in the current period is equal to the number of machines/workers in the previous period, as well as the number of machines/workers transferred in, and minus the number of machines/workers transferred out. | Nouri (2016), Bayram & Sahin (2016), Khannan et al. (2016), Dalfard (2013), Deljoo et al. (2010) |
| Each part demand can be satisfied in time period through internal production or subcontracting part operation | Deep & Singh (2015), Rezazadeh et al. (2011) |
| All the consecutive operations of part type consist of equal production quantities, thus a part operation can be internally processed or subcontracted to satisfy the part demand. | Deep & Singh (2015) |
| Total number of machines of each type assigned to cells is less than or equal to the number of machines of the same type that are available | Khannan et al. (2016), Deep & Singh (2015), Dalfard (2013), Mahdhavi, Aalaei et al. (2012) |
| Assign each machine to one cell only to avoid machine sharing | Khannan et al. (2016), Bagheri & Bashiri (2014), Shiyas, & Pillai (2014), Dalfard (2013), Hamedi et al. (2012), Deljoo et al. (2010) |
| Allocates operations of parts to one of the machines capable to perform the operation | Dalfard (2013) |
| Each employee can be assigned to work at his/her real skill level or at any lower skill level in each shift | Shahnazari-Shahrezaei, Tavakkoli-Moghaddam, & Kazemipoor (2013) |
| Upper bound on the total number of daily hours worked by each employee | Shahnazari-Shahrezaei et al. (2013) |
| Lower and upper bound on the total number of hours worked by each employee during the planning period | Shahnazari-Shahrezaei et al. (2013) |
| Each employee cannot be assigned to work in two successive shifts | Shahnazari-Shahrezaei et al. (2013) |
| Each employee who is assigned to work in two non-successive shifts of a day should be off for the next day | Shahnazari-Shahrezaei et al. (2013) |
| Each employee can just be assigned to work at one skill level in each shift of any day | Shahnazari-Shahrezaei et al. (2013) |
| Employers tend to pay the minimum penalty for assigning the employees at lower skill levels than their real skill | Shahnazari-Shahrezaei et al. (2013) |
| Employees tend to work equal to working hours that they have specified at the beginning | Shahnazari-Shahrezaei et al. (2013) |

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| | |
|---|---|
| of planning | |
| Ensures that only one routing is selected for each part type | Mohammadi & Forghani (2014) |
| Machines belonging to the same cell do not overlap in the x-axis and y-axis | Mohammadi & Forghani (2014) |
| Calculate the length and width of cell based on the dimensions of the machines assigned to it | Mohammadi & Forghani (2014) |
| Measure the width and length of each machine (in the x- and y-axis, respectively) based on its orientation | Mohammadi & Forghani (2014) |
| To balance the load among formed cells, the load of each cell should be higher than a percent of overall load of all cells | Hamedi et al. (2012), Rezazadeh et al. (2011) |
| Each worker will be assigned to only one Cell | Bagheri & Bashiri (2014), Mahdhavi, Aalaei et al. (2012) |
| Each part type is assigned to only one cell | Khannan et al. (2016), Mahdhavi, Aalaei et al. (2012) |
| If one part type is required to be processed by one machine type, more than one worker would be able to service this machine type | Mahdhavi, Aalaei et al. (2012) |
| Lower bound for the number of parts to be allocated to each cell | Mahdhavi, Aalaei et al. (2012) |
| Limit the minimum number of operators assigned to cell | Mahdhavi, Aalaei et al. (2012) |
| Ensures that the minimum numbers of operators are hired | Bagheri & Bashiri (2014) |
| That an operator can be assigned to a machine and a cell, respectively, if has been hired in that period | Bagheri & Bashiri (2014) |
| Minimum and maximum number of operators required by each machine is restricted | Egilmez et al. (2014), Bagheri & Bashiri (2014) |
| The maximum and Minimum number of machines that each operator can operate with is restricted | Bagheri & Bashiri (2014) |
| Trained operator in a period will not need to learn again to work with the same machine. | Bagheri & Bashiri (2014) |
| Each cell should be assigned to only one candidate location and a location can be opened only for one cell. | Bayram & Sahin (2016), Bagheri & Bashiri (2014) |
| Ensure that an operation of a given product type can only be processed in a given location if a machine, which is capable of this operation, is assigned to the location. | Bayram & Sahin (2016) |
| Total number of processed parts cannot exceed the demand for the product | Bayram & Sahin (2016) |
| Total processing time of the operations routed | Bayram & Sahin (2016), Khannan |

| | |
|---|---|
| to a machine cannot exceed its capacity, which is defined in terms of time | et al. (2016) |
| Ensure that the total number of incoming products from all other locations to a location for its next operation is equal to the number of products which receive their next operation in the given location | Bayram & Sahin (2016) |
| Assure that the number of operators assigned to each operation is large enough to achieve the maximum production rate with respect to the risk level | Egilmez et al. (2014) |
| Total number of product operations processed anywhere in the factory floor must be equal to the total product demand | Bayram & Sahin (2016) |
| Total number of operators assigned to all operations cannot exceed the total number of operators available for cells | Egilmez et al. (2014) |
| If a part has not been produced in a period, none of its operation should have been dedicated to a machine, and cell | |
| One operator is assigned to one machine only | Khannan et al. (2016) |
| Lower and upper bound for subcontracting quantity for each part in each period | Khannan et al. (2016) |
| Inventory and backorder level must be zero at the end of periods | Khannan et al. (2016) |
| Ensures that inventory and backorder cannot happen simultaneously | Khannan et al. (2016) |
| A task is processed on an equipment type at a workstation only if that equipment is assigned to that workstation | Jayaswal, & Agarwal (2014) |

# APPENDIX B: Questionnaire QE 1

**Introduction**

Questionnaire (QE 1) was distributed to obtain necessary data on research problem justification, selection of an appropriate layout type, and to select the product category for subsequent stages of the research. It was advised to answer the questions with respect to orders in quantity range of 50 to 4000 pieces per order.

**Questionnaire (QE 1)**

**QE 1.1** Machine types used for operations in production department

☐ Semi-automatic machines

☐ Fully automatic machines

**QE 1.2** Rate the problems that are contributing to increased changeover time in production department. Rating scale: 5 – Highly frequent, 1 – Least frequent

| Problems | Rating | | | | |
|---|---|---|---|---|---|
| | 5 | 3 | 4 | 2 | 1 |
| Increased machine movement between different locations | | | | | |
| Increased machine setting and adjustment | | | | | |
| Increased operator training time | | | | | |
| Increased defect rate | | | | | |
| Raw material delays | | | | | |
| Poor coordination with supporting departments | | | | | |
| Insufficient number of operators | | | | | |
| Machine breakdowns | | | | | |
| Other | | | | | |

**QE 1.3** Rate the factors to include in layout design for fast fashion orders.

Rating scale: 5 – Highly important, 1 – Least important

| Factor | Rating | | | | |
|---|---|---|---|---|---|
| | 5 | 4 | 3 | 2 | 1 |
| Reduce total machine setup time | | | | | |
| Minimize machine movements | | | | | |
| Reduce material handling complexity | | | | | |
| Reduce WIP | | | | | |
| Reduce material handling cost | | | | | |
| Increase the ease of supervision | | | | | |
| Other | | | | | |

**QE 1.4** Select the product category/categories with highest demand for fast fashion orders.

☐ Intimate apparels

☐ Casual wear

☐ Active wear

☐ Outer wear

☐ Sleep wear

☐ Children's wear

☐ Work wear

Other (Please specify):

## APPENDIX C: Questionnaire QE 2

**Introduction**

Summary of the selected design attributes based on the perspective of Factory 1 are used in questionnaire (QE 2). QE 2 was developed to identify the design attributes to include in the developed production layout planning system for fast fashion apparels. It was advised to select the relevant options based on orders in quantity range of 50 to 4000 pieces per order. Furthermore, it was advised to mention if a particular option is not available in current situation and factories consider it as essential to include in developed system. If the factory does not currently use cellular layouts, it was advised to select the options based on existing layout.

The percentages of responses received for each option is indicated.

**Questionnaire (QE 2) and its results**

**QE 2.1 Input data:** State the current availability and importance of considering following data in a layout design for fast fashion apparels

| Input data | Percentage of responses | | | |
| --- | --- | --- | --- | --- |
| | Currently available | | Important | |
| | *Yes* | *No* | *Yes* | *No* |
| Length of planning horizon with confirmed order details | 98.4 | - | 98.4 | - |
| Planned number of pieces per day for each part type | 99.5 | - | 99.5 | - |
| Bundle size for part types | 99.5 | - | 99.5 | - |
| SMVs of each operation | 99.5 | - | 99.5 | - |
| Operation sequence | 99.5 | - | 99.5 | - |
| Average time taken to load and unload machines to/from the hand truck | 78.1 | - | 98.3 | - |
| Cost per standard minute value for part types | 99.5 | - | 99.5 | - |
| Production downtime data | 84.6 | - | 99.5 | - |
| Total working minutes per day | 99.5 | - | 99.5 | - |
| Total number of days available to produce each part type in production department | 99.5 | - | 99.5 | - |
| Expected daily production efficiency for each part type | 99.5 | - | 99.5 | - |
| Planned order schedule | 99.5 | - | 99.5 | - |
| Number of working days in considered planning horizon | 99.5 | - | 99.5 | - |
| Average number of turning motions (45 to 90 degrees) when moving materials between layouts | | | | |
| Maximum number of layouts that can be simultaneously changed by mechanics | | | | |
| Number of available machines in each machine type | 99.5 | - | 99.5 | - |
| Machine settings required for operations with respective times | | | | |
| Required minimum distance between adjacent machine rows | | | | |
| Coordinates of the machine set-up area | | | | |
| Dimensions of the machines, input/output boxes, and usable area for layouts | | | | |
| Other (Please mention any additional comments) | | | | |

**QE 2.2 Assumptions:** State the current applicability and importance of considering following assumptions in a layout design for fast fashion apparels

| Assumption | Percentage of responses | | | |
|---|---|---|---|---|
| | Currently applicable | | Important | |
| | *Yes* | *No* | *Yes* | *No* |
| Adequate number of machines and operators are available for each planning period. | 75.1 | 24.9 | 88.3 | 11.7 |
| Multi-skilled pool of operators and mechanics is available to cover up absenteeism. | 62.5 | 37.5 | 82.7 | 17.3 |
| SMVs for each operation and each machine setup activity are defined. | 95.9 | 4.1 | 98.2 | 1.8 |
| Fixed machine set-up area is provided for machine set-up activities and operator training during changeovers, and to store additional machines. | 96.7 | 3.3 | 98.2 | 1.8 |
| Details of the upcoming orders are known in advance. | 96.7 | 3.3 | 98.2 | 1.8 |
| Simultaneous processing of multiple part types in a single layout is prohibited. | 98.2 | 1.8 | 98.2 | 1.8 |
| All the operators are in stand-up position. | 43.4 | 56.6 | 79.1 | 20.9 |
| Machine sharing between operators is not allowed. | 88.8 | 11.2 | 88.8 | 11.2 |
| Layout reconfiguration (if any) includes machine setup activities and machine relocations between and/or within the cells. In addition, machines are moved from/to machine set-up area to/from cells. | 96.7 | 3.3 | 96.7 | 3.3 |
| Physical partitioning of the cells is prohibited. Furthermore, layout reconfiguration does not require modifications to the buildings. Therefore, other than the machine relocation costs, any physical reconfiguration costs (i.e. changes in lighting and ventilation systems) are not allowed. | 98.2 | 1.8 | 98.2 | 1.8 |
| Adequate lighting and environmental conditions required for the operations are provided. Additional light bulbs are attached to the machines when necessary. | 87.2 | 12.8 | 98.2 | 1.8 |
| Multiple duplicate machines of each type are available. Existing machines are utilized when developing the layouts. | 98.2 | 1.8 | 98.2 | 1.8 |
| Machine working time is reduced due to production downtimes. | 98.2 | 1.8 | 98.2 | 1.8 |
| Bundle size for material handling between the machines and/or cells is defined. | 71.2 | 28.8 | 83.4 | 16.6 |
| Other (Please mention any additional comments) | | | | |

**QE 2.3 Cost terms:** State the current applicability and importance of considering following cost terms in a layout design for fast fashion apparels

| Cost terms | Percentage of responses | | | |
| --- | --- | --- | --- | --- |
| | Currently applicable | | Important | |
| | *Yes* | *No* | *Yes* | *No* |
| Inter-cell machine relocation cost | 50.3 | - | 82.1 | - |
| Intra-cell machine relocation cost | 85.5 | 14.5 | 96.4 | - |
| Machine set-up cost | 79.9 | - | 96.4 | - |
| Inter-cell material handling cost | 51.1 | - | 82.1 | - |
| Intra-cell material handling cost | 85.5 | 14.5 | 96.4 | - |
| Cost of deviation between target cycle time per bundle and workstation cycle times | 72.3 | - | 96.4 | - |
| Cost of cycle time deviation between bottleneck workstation and other workstations | 72.3 | - | 96.4 | - |
| Other (Please mention any additional comments) | | | | |

**QE 2.4 Constraints:** State the current applicability and importance of considering following constraints in a layout design for fast fashion apparels.

| Constraint | Percentage of responses | | | |
| --- | --- | --- | --- | --- |
| | Currently applicable | | Important | |
| | *Yes* | *No* | *Yes* | *No* |
| Maximum number of layouts that can be simultaneously changed is limited | 98.4 | - | 98.4 | - |
| Balance the workload between cells | 70.2 | 29.8 | 81.1 | - |
| Prevent utilizing of machine by exceeding its capacity | 95.6 | 4.4 | 98.4 | - |
| Use only the available machines on plant floor | 82.6 | 17.4 | 98.4 | - |
| Ensure non-overlapping of machines, layouts, and gangways | 81.1 | - | 98.4 | - |
| Prevent the developed cells from exceeding available floor dimensions | 95.6 | - | 98.4 | - |
| Improve area utilization | 81.8 | - | 98.4 | - |
| Limit the part processing capability of all machine types based on total machine capacity available for individual machine types | 83.6 | - | 95.6 | - |
| Ensure that the resultant daily efficiency is greater than or equal to planned daily efficiency for each part type assembled in each cell | 84.3 | - | 98.4 | - |
| Ensure that each workstation cycle time is less than or equal to the target cycle time of defined bundle size | 88.8 | - | 98.4 | - |
| Theoretical number of operator/machines should be greater than or equal to resultant number of operators in developed cells | 80.1 | - | 98.4 | - |
| Ensure only one part type is assembled at a time in each cell | 79.2 | - | 98.4 | - |
| Prevent the assignment of a single machine to more than one cell | 81.6 | - | 88.8 | - |
| Assign each operator to a single workstation only | 78.5 | - | 98.4 | - |
| Assign one machine only to a single location | | - | 98.4 | - |
| Limit the maximum allowable number of operations per operator | 92.6 | - | 98.4 | - |
| Other (Please mention any additional comments) | | | | |

# APPENDIX D: Sample of the program code

Sample of the program code of the developed system is given.

MODEL:

SETS:

! Specify number jobs, families, machine types;

JOBS/1 .. 12/:JOBPRIORITY;

FAMILIES/1 .. 3/;

MTYPES/1 .. 5/:THETA,VMPLUS,VMMINUS;

CELLS/1 .. 3/:NOWORKERS;

!----------------------------------------------------------;

! required processing times;

JOBMTYP(JOBS,MTYPES):PROCTIME;

! required setup times;

FAMMTYPE(FAMILIES,MTYPES):MAJSET;

! job families;

JOBSFAM(JOBS,FAMILIES):SF;

!----------------------------------------------------------;

! decision variables;

JOBCELL(JOBS,CELLS):XIK;

MTYPCELL(MTYPES,CELLS):MK,NMK,TMK;

FAMCELLMTYPE(FAMILIES,CELLS,MTYPES):ZFKM;

JOBCELLMTYPE(JOBS,CELLS,MTYPES):YIKM;

ENDSETS

STIME>0;

!----------------------------------------------------------;

DATA:

! import the data from excel;

SF,MAJSET,THETA,PROCTIME,RL,L,MAXW,MINW,ALPHA,

JOBPRIORITY = @OLE('G:\all dirs\papers\wip\virtual

cells\data13.xls');

! export the data back to excel;

@OLE('G:\all dirs\papers\wip\virtual cells\data13.xls')=

NOWORKERS,XIK,YIKM,ZFKM,MK,NMK,TMK,VMPLUS,VMMINUS,STIME;

ENDDATA

!---------------------------------------------------------;

[OBJECTIVE]MAX=

100*(@SUM(JOBS(I):@SUM(CELLS(K):@SUM(MTYPES(M):PROCTIME(I,M)

* XIK(I,K)))))- 10 * (@SUM(MTYPES(M):VMPLUS(M)))+

@SUM(MTYPES(M):VMMINUS(M));

!---------------------------------------------------------;

STIME =

(@SUM(JOBS(I):@SUM(CELLS(K):@SUM(MTYPES(M):PROCTIME(I,M)

* XIK(I,K)))));

!---------------------------------------------------------;

@FOR(JOBS(I):

[CO2] @SUM(CELLS(K):XIK(I,K)) <= 1);

@FOR(JOBS(I)|JOBPRIORITY(I)#EQ#1:

[CO3]@SUM(CELLS(K):XIK(I,K)) = 1);

[CO4]@SUM(CELLS(K):NOWORKERS(K)) <= L;

@FOR(MTYPES(M):

[CO5]@SUM(CELLS(K):NMK(M,K))<=THETA(M));

@FOR(MTYPES(M):@FOR(CELLS(K):

[CO6]MK(M,K)>= NMK(M,K)));

@FOR(MTYPES(M):

[CO7]@SUM(CELLS(K):MK(M,K))<= THETA(M) +

VMPLUS(M) - VMMINUS(M));

@FOR(JOBS(I):@FOR(CELLS(K):@FOR(MTYPES(M):

[CO8] XIK(I,K)*PROCTIME(I,M)<= 10000 *

YIKM(I,K,M))));

@FOR(FAMILIES(F):@FOR(CELLS(K):@FOR(MTYPES(M):

[CO9] @SUM(JOBS(I)|SF(I,F)#EQ#1:YIKM(I,K,M))<=

10000 * ZFKM(F,K,M))));

@FOR(CELLS(K):

[C10] @SUM(JOBS(I):@SUM(MTYPES(M): PROCTIME(I,M) *

YIKM(I,K,M))) +

@SUM(FAMILIES(F):@SUM(MTYPES(M): (ZFKM(F,K,M)+ ALPHA*

(@SUM(JOBS(I)|SF(I,F)#EQ#1:YIKM(I,K,M))-

ZFKM(F,K,M)))*MAJSET(F,M)))<=NOWORKERS(K) *RL);

@FOR(CELLS(K):@FOR(MTYPES(M):

[C11]@SUM(JOBS(I): PROCTIME(I,M) * YIKM(I,K,M)) +

@SUM(FAMILIES(F): (ZFKM(F,K,M) + ALPHA *

(@SUM(JOBS(I)|SF(I,F)#EQ#1:YIKM(I,K,M))-

ZFKM(F,K,M))) *MAJSET(F,M))<=NMK(M,K) * RL));

@FOR(CELLS(K):@FOR(MTYPES(M):

[C12]TMK(M,K)= @SUM(JOBS(I):PROCTIME(I,M) * YIKM(I,K,M)) +

@SUM(FAMILIES(F): (ZFKM(F,K,M) + ALPHA *

(@SUM(JOBS(I)|SF(I,F)#EQ#1:YIKM(I,K,M))-ZFKM(F,K,M)))

*MAJSET(F,M))));

@FOR(CELLS(K):

[C13] NOWORKERS(K) <= MAXW);

@FOR(CELLS(K):

[C14] NOWORKERS(K) >= MINW);

@FOR(JOBCELL(I,K):

[C15]@BIN(XIK(I,K)));

@FOR(JOBCELLMTYPE(I,K,M):

[C16]@BIN(YIKM(I,K,M)));

@FOR(FAMCELLMTYPE(F,K,M):

[C17]@BIN(ZFKM(F,K,M)));

@FOR(MTYPCELL(M,K):

[C18]@GIN(MK(M,K)));

@FOR(MTYPES(M):

[C19]@GIN(VMPLUS(M)));

@FOR(MTYPES(M):

[C20]@GIN(VMMINUS(M)));

END

## APPENDIX E: MTM data tables

MTM codes and respective TMU values relevant for walking are given.

Source: Mital et al. (2017) and Karger and Bahya (1987)

| Motion | MTM code | Distance | TMU |
|---|---|---|---|
| Side step | | | |
| Case 1: Complete when leading leg contacts the floor | SSC1 | Less than or equal to 30 cm | 17.0 |
| | | Each additional 1 cm | 0.2 |
| Case 2: Lagging leg must contact floor before next motion can be made | SSC2 | Less than or equal to 30 cm | 34.1 |
| | | Each additional 1 cm | 0.4 |
| Turn body: 45 to 90 degrees | | | |
| Case 1: Complete when leading leg contacts the floor | TBC1 | | 18.6 |
| Case 2: Lagging leg must contact floor before next motion can be made | TBC2 | | 37.2 |
| Walk: Obstructed | W-PO | Per pace or per feet | 17.0 |
| Sit | SIT | | 34.7 |
| Standing from seated position | STD | | 43.4 |

## APPENDIX F: Input and output data of system evaluation

### Input data used for Factory 1

Production volume and expected daily efficiency in Factory 1

| $t$ | $\tau$ | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| 1 | 1001 | 1167 | 1334 |
| 2 | 948 | 1106 | |
| 3 | 1015 | 1184 | 1353 |
| 4 | 967 | 1128 | 1289 |
| 5 | 1046 | 1220 | |
| 6 | 844 | 985 | 1126 |
| 7 | 770 | 898 | 1027 |
| 8 | 841 | 981 | 1122 |
| Efficiency ladder | 30% | 35% | 40% |

Machine types required for operations of part types in Factory 1

| $n$ | $t$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1 | 1 | 2 | 1 | 11 | 11 | 1 | 1 | 11 |
| 2 | 2 | 10 | 2 | 1 | 1 | 2 | 2 | 1 |
| 3 | 4 | 1 | 5 | 2 | 2 | 7 | 5 | 4 |
| 4 | 6 | 4 | 8 | 4 | 4 | 10 | 8 | 2 |
| 5 | 13 | 4 | 8 | 6 | 5 | 9 | 8 | 5 |
| 6 | 5 | 7 | 9 | 1 | 5 | 9 | 7 | 3 |
| 7 | 5 | 7 | 8 | 5 | 6 | 9 | 9 | 8 |
| 8 | 6 | 9 | 9 | 5 | 8 | 13 | 1 | 10 |
| 9 | 7 | 10 | 12 | 8 | 1 | 4 | 13 | 7 |
| 10 | 8 | 12 | 13 | 9 | 1 | 13 | 13 | 10 |
| 11 | 10 | 13 | 13 | 12 | 6 | 13 | 13 | 13 |
| 12 | 10 | 13 | | 13 | 12 | | | 13 |
| 13 | 13 | | | 13 | 13 | | | 13 |
| 14 | 13 | | | | 13 | | | 13 |

Machine settings required for operations of part types in Factory 1

| $n$ | $t$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1 | 6 | 6 | 1 | 11 | 11 | 2 | 5 | 11 |
| 2 | 4 | 2 | 9 | 4 | 7 | 6 | 1 | 6 |
| 3 | 9 | 2 | 3 | 7 | 5 | 9 | 5 | 2 |
| 4 | 2 | 4 | 9 | 2 | 2 | 4 | 2 | 5 |
| 5 | 13 | 2 | 2 | 7 | 6 | 2 | 1 | 2 |
| 6 | 4 | 3 | 2 | 7 | 2 | 2 | 9 | 5 |
| 7 | 1 | 9 | 3 | 5 | 8 | 5 | 3 | 1 |
| 8 | 9 | 6 | 5 | 7 | 3 | 9 | 1 | 4 |
| 9 | 9 | 6 | 12 | 9 | 5 | 2 | 13 | 4 |
| 10 | 7 | 12 | 13 | 3 | 7 | 13 | 13 | 4 |
| 11 | 8 | 13 | 13 | 12 | 9 | 13 | 13 | 13 |
| 12 | 4 | 13 |  | 13 | 12 |  |  | 5 |
| 13 | 13 |  |  | 13 | 13 |  |  | 13 |
| 14 | 13 |  |  |  | 13 |  |  | 13 |

SMVs of respective operations of part types in Factory 1

| $n$ | $t$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1 | 0.1582 | 0.3615 | 0.3284 | 0.4517 | 0.4602 | 0.3500 | 0.2749 | 0.2156 |
| 2 | 0.2340 | 0.2041 | 0.1282 | 0.3512 | 0.1149 | 0.4231 | 0.2780 | 0.1488 |
| 3 | 0.5666 | 0.4244 | 0.3924 | 0.1118 | 0.0131 | 0.1526 | 0.4572 | 0.5263 |
| 4 | 0.5559 | 0.3070 | 0.4419 | 0.3860 | 0.2507 | 0.2479 | 0.0225 | 0.0077 |
| 5 | 0.1962 | 0.0107 | 0.0481 | 0.3379 | 0.2459 | 0.3987 | 0.3682 | 0.4186 |
| 6 | 0.0504 | 0.3322 | 0.0396 | 0.0249 | 0.3984 | 0.1406 | 0.4549 | 0.2866 |
| 7 | 0.1752 | 0.1300 | 0.3077 | 0.3574 | 0.0914 | 0.3988 | 0.3217 | 0.1834 |
| 8 | 0.1297 | 0.3393 | 0.0823 | 0.3199 | 0.0399 | 0.1735 | 0.3802 | 0.0241 |
| 9 | 0.1545 | 0.2550 | 0.4607 | 0.2621 | 0.0865 | 0.2838 | 0.2796 | 0.5452 |
| 10 | 0.1363 | 0.1693 | 0.0241 | 0.0585 | 0.3420 | 0.2300 | 0.2095 | 0.0133 |
| 11 | 0.4398 | 0.2518 | 0.2447 | 0.2459 | 0.2528 | 0.2028 | 0.2437 | 0.2947 |
| 12 | 0.1038 | 0.1316 |  | 0.1734 | 0.2019 |  |  | 0.3999 |
| 13 | 0.1751 |  |  | 0.0185 | 0.2782 |  |  | 0.4663 |
| 14 | 0.1485 |  |  |  | 0.3085 |  |  | 0.3047 |

Machine setup times for respective settings on each machine type in Factory 1

| $i$ | $l$ | | | | | | | | | |
|----|------|------|------|------|------|------|------|------|------|------|
|    | 1    | 2    | 3    | 4    | 5    | 6    | 7    | 8    | 9    | 10   |
| 1  | 1.17 | 1.07 | 1.08 | 3.05 | 1.73 | 2.10 | 0.72 | 1.98 | 1.87 |      |
| 2  | 0.83 | 2.39 | 0.86 | 2.30 | 2.59 | 1.13 | 1.55 | 1.18 | 2.75 |      |
| 3  | 1.05 | 3.02 | 0.94 | 2.94 | 0.95 | 1.54 | 1.76 | 1.21 | 2.20 |      |
| 4  | 0.86 | 2.05 | 1.91 | 1.77 | 1.17 | 1.47 | 3.28 | 1.07 | 2.50 |      |
| 5  | 1.03 | 1.88 | 1.28 | 0.05 | 1.35 | 2.32 | 1.69 | 0.51 | 1.04 |      |
| 6  | 1.54 | 1.03 | 1.11 | 1.55 | 1.58 | 2.50 | 1.48 | 0.65 | 3.20 |      |
| 7  | 1.45 | 2.00 | 1.05 | 0.42 | 2.69 | 1.28 | 3.12 | 2.06 | 3.27 |      |
| 8  | 1.83 | 1.01 | 1.71 | 0.49 | 2.76 | 1.32 | 2.85 | 1.12 | 1.26 |      |
| 9  | 0.04 | 2.16 | 1.73 | 1.50 | 1.26 | 2.30 | 0.70 | 0.81 | 1.80 |      |
| 10 | 1.09 | 2.41 | 1.36 | 0.49 | 0.70 | 2.34 | 1.61 | 0.62 | 2.83 |      |
| 11 |      |      |      |      |      |      |      |      |      | 0.68 |
| 12 |      |      |      |      |      |      |      |      |      | 0.68 |

Random numbers generated based on production downtimes in Factory 1

| | | | | | | | | |
|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| 10.774 | 23.689 | 34.960 | 20.385 | 10.769 | 4.656  | 42.158 | 4.171  | 39.180 |
| 28.177 | 5.347  | 6.389  | 25.312 | 14.159 | 15.493 | 26.146 | 18.277 | 18.463 |
| 36.687 | 11.504 | 34.982 | 22.801 | 19.787 | 32.533 | 8.933  | 3.294  | 37.533 |
| 23.361 | 34.916 | 29.903 | 20.915 | 34.874 | 25.426 | 1.181  | 9.007  | 14.848 |
| 13.523 | 5.526  | 29.438 | 16.404 | 36.907 | 18.813 | 30.015 | 12.557 | 0.386  |
| 32.935 | 4.396  | 23.995 | 35.131 | 41.863 | 25.865 | 33.426 | 2.760  | 37.208 |
| 30.226 | 24.070 | 9.702  | 30.323 | 40.446 | 10.027 | 36.392 | 0.483  | 10.544 |
| 30.564 | 38.669 | 23.290 | 20.552 | 41.422 | 32.984 | 18.536 | 17.481 | 5.975  |
| 36.003 | 8.434  | 41.306 | 31.994 | 5.561  | 1.363  | 17.258 | 24.560 | 6.046  |
| 27.456 | 40.089 | 21.506 | 1.572  | 15.127 | 16.405 | 3.516  | 11.654 | 36.547 |
| 5.588  | 36.128 | 32.626 | 0.018  | 0.464  | 3.181  | 5.357  | 28.989 | 13.007 |
| 32.923 | 21.032 | 34.198 | 32.336 | 39.793 | 1.447  | 1.164  | 4.909  | 37.676 |
| 1.291  | 1.141  | 6.656  | 0.129  | 31.922 | 20.848 | 40.622 | 0.810  | 35.711 |
| 31.529 | 34.399 | 13.570 | 40.796 | 40.468 | 38.797 | 15.138 | 11.794 | 37.154 |
| 15.460 | 2.683  | 4.961  | 29.951 | 23.173 | 1.636  | 10.110 | 25.742 | 41.064 |
| 28.664 | 40.306 | 16.737 | 9.610  | 40.278 | 37.286 | 11.857 | 32.860 | 33.423 |
| 7.832  | 32.645 | 11.701 | 36.996 | 7.304  | 26.710 | 30.866 | 3.708  | 37.731 |
| 11.585 | 4.791  | 18.825 | 13.263 | 41.819 | 34.662 | 18.030 | 25.907 | 27.975 |
| 31.565 | 39.769 | 22.854 | 36.896 | 23.379 | 41.190 | 37.603 | 40.845 | 14.046 |

Number of available machines of each type in Factory 1

| $i$ | Total number of available machines |
|---|---|
| 1 | 33 |
| 2 | 20 |
| 3 | 12 |
| 4 | 24 |
| 5 | 28 |
| 6 | 22 |
| 7 | 22 |
| 8 | 17 |
| 9 | 29 |
| 10 | 25 |
| 11 | 14 |
| 12 | 16 |
| 13 | 43 |

Order sequence in Factory 1: 1,2,3,4 to 5,6,7,8

Dimensional input data of Factory 1 (measured in meters)

| Input data | Factory 1 |
|---|---|
| $L_{PF}$ | 65.51 |
| $W_{PF}$ | 48.62 |
| $max\left\{L_{m_{ij}}, L_{oC_k}\right\}$ | 1.25 |
| $max\left\{W_{m_{ij}}, W_{oC_k}\right\}$ | 1.06 |
| $W_\beta$ | 1 |
| $x_D$ | 95.3 |
| $y_D$ | 90.35 |

Other input data used for Factory 1

| Input data | Factory 1 |
|---|---|
| $U_{m_{i,j}}$ (min) | 5.21 |
| $B_t$ (pieces) | 5 |
| $\gamma_t$ (\$) | 3.2 |
| $\xi$ (min) | 960 |
| $\psi$ | 2 |
| $\lambda$ | 11 |

**Output data of Factory 1**

Part family groups in Factory 1

| b | t | k |
|---|-----|---------|
| 1 | 1,8 | 1, 8 |
| 2 | 2,3,6,7 | 2 ,3, 6, 7 |
| 3 | 4,5 | 4,5 |

Number of machines of each machine type in the dynamic cells in Factory 1

| i | k | | | | | | | |
|----|---|---|---|---|---|---|---|---|
|    | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1  | 1 | 1 | 2 | 4 | 4 | 1 | 2 | 1 |
| 2  | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 2 |
| 3  | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 4  | 1 | 3 | 0 | 2 | 1 | 1 | 0 | 1 |
| 5  | 2 | 0 | 1 | 3 | 2 | 0 | 1 | 1 |
| 6  | 2 | 0 | 0 | 2 | 2 | 0 | 0 | 0 |
| 7  | 1 | 2 | 0 | 0 | 0 | 2 | 2 | 1 |
| 8  | 1 | 0 | 5 | 1 | 2 | 0 | 3 | 1 |
| 9  | 0 | 3 | 3 | 1 | 0 | 4 | 2 | 0 |
| 10 | 3 | 2 | 0 | 0 | 0 | 3 | 0 | 3 |
| 11 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 |
| 12 | 0 | 2 | 1 | 1 | 2 | 0 | 0 | 0 |
| 13 | 4 | 2 | 2 | 2 | 3 | 3 | 4 | 4 |

Operator assignment to operations in dynamic cells in Factory 1

| n | k | | | | | | | |
|----|-------|-------|-------|-------|-----|-------|-------|-------|
|    | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1  | 1 | 1,2 | 1,2 | 1,2 | 1,2 | 1,2 | 1 | 1 |
| 2  | 2 | 3 | 3 | 3,4 | 3 | 3,4 | 2 | 2 |
| 3  | 3,4 | 4,5 | 4,5 | 5 | 3 | 5 | 3,4 | 3,4 |
| 4  | 5,6 | 6 | 6,7 | 5,6 | 4 | 6 | 4 | 4 |
| 5  | 7 | 7 | 8 | 7,8 | 5 | 7,8 | 5,6 | 5,6 |
| 6  | 7 | 7,8 | 8 | 8 | 6,7 | 9 | 7,8 | 7 |
| 7  | 8 | 9 | 9,10 | 9,10 | 7 | 10,11 | 9 | 8 |
| 8  | 9 | 10,11 | 10 | 10,11 | 8 | 12 | 10,11 | 8 |
| 9  | 10 | 12 | 11,12 | 12 | 8 | 13 | 12 | 9,10 |
| 10 | 11 | 13 | 13 | 12 | 8,9 | 14 | 13 | 10 |
| 11 | 12,13 | 14 | 14 | 13 | 10 | 15 | 14 | 11 |
| 12 | 14 | 15 | | 14 | 11 | | | 12 |
| 13 | 14 | | | 14 | 12 | | | 13,14 |
| 14 | 15 | | | | 13 | | | 15 |

Coordinates of dynamic cell locations in Factory 1

| k | x | y |
|---|---|---|
| 1 | 6.16 | 2.31 |
| 2 | 18.84 | 2.31 |
| 3 | 18.84 | 7.93 |
| 4 | 6.16 | 7.93 |
| 5 | 6.16 | 7.93 |
| 6 | 18.84 | 2.31 |
| 7 | 18.84 | 7.93 |
| 8 | 6.16 | 2.31 |

Machine type at each location in Factory 1

| g | k | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1 | 1 | 2 | 1 | 11 | 11 | 1 | 1 | 11 |
| 2 | 2 | 10 | 1 | 1 | 1 | 2 | 2 | 1 |
| 3 | 4 | 1 | 2 | 1 | 1 | 7 | 5 | 4 |
| 4 | 6 | 4 | 2 | 2 | 2 | 7 | 8 | 2 |
| 5 | 2 | 4 | 5 | 4 | 4 | 10 | 8 | 2 |
| 6 | 5 | 4 | 8 | 4 | 5 | 10 | 8 | 5 |
| 7 | 5 | 7 | 8 | 6 | 5 | 10 | 7 | 3 |
| 8 | 6 | 7 | 8 | 6 | 6 | 9 | 7 | 3 |
| 9 | 7 | 9 | 8 | 1 | 8 | 9 | 9 | 8 |
| 10 | 8 | 9 | 9 | 1 | 8 | 9 | 9 | 10 |
| 11 | 10 | 9 | 8 | 5 | 1 | 9 | 1 | 10 |
| 12 | 10 | 10 | 9 | 5 | 1 | 13 | 13 | 7 |
| 13 | 10 | 12 | 9 | 5 | 6 | 4 | 13 | 10 |
| 14 | 13 | 12 | 12 | 8 | 12 | 13 | 13 | 13 |
| 15 | 13 | 13 | 13 | 9 | 12 | 13 | 13 | 13 |
| 16 | 13 | 13 | 13 | 12 | 13 | | | 13 |
| 17 | 13 | | | 13 | 13 | | | 13 |
| 18 | | | | 13 | 13 | | | |

x-coordinate values for machine locations in dynamic cells in Factory 1

| g | k | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1 | 1.88 | 15.19 | 15.19 | 1.88 | 1.88 | 15.19 | 15.19 | 1.88 |
| 2 | 3.13 | 16.44 | 16.44 | 3.13 | 3.13 | 16.44 | 16.44 | 3.13 |
| 3 | 4.38 | 17.69 | 17.69 | 4.38 | 4.38 | 17.69 | 17.69 | 4.38 |
| 4 | 5.63 | 18.94 | 18.94 | 5.63 | 5.63 | 18.94 | 18.94 | 5.63 |
| 5 | 6.88 | 20.19 | 20.19 | 6.88 | 6.88 | 20.19 | 20.19 | 6.88 |
| 6 | 8.13 | 21.44 | 21.44 | 8.13 | 8.13 | 21.44 | 21.44 | 8.13 |
| 7 | 9.38 | 22.69 | 22.69 | 9.38 | 9.38 | 22.69 | 22.69 | 9.38 |
| 8 | 10.63 | 23.84 | 23.84 | 10.63 | 10.63 | 23.84 | 23.84 | 10.63 |
| 9 | 11.78 | 23.84 | 23.84 | 11.78 | 11.78 | 23.84 | 23.84 | 11.78 |
| 10 | 11.78 | 22.69 | 22.69 | 11.78 | 11.78 | 22.69 | 22.69 | 11.78 |
| 11 | 10.63 | 21.44 | 21.44 | 10.63 | 10.63 | 21.44 | 21.44 | 10.63 |
| 12 | 9.38 | 20.19 | 20.19 | 9.38 | 9.38 | 20.19 | 20.19 | 9.38 |
| 13 | 8.13 | 18.94 | 18.94 | 8.13 | 8.13 | 18.94 | 18.94 | 8.13 |
| 14 | 6.88 | 17.69 | 17.69 | 6.88 | 6.88 | 17.69 | 17.69 | 6.88 |
| 15 | 5.63 | 16.44 | 16.44 | 5.63 | 5.63 | 16.44 | 16.44 | 5.63 |
| 16 | 4.38 | 15.19 | 15.19 | 4.38 | 4.38 | | | 4.38 |
| 17 | 3.13 | | | 3.13 | 3.13 | | | 3.13 |
| 18 | | | | 1.88 | 1.88 | | | |

y-coordinate values for machine locations in dynamic cells in Factory 1

| g | k | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1 | 0.53 | 0.53 | 6.15 | 6.15 | 6.15 | 0.53 | 6.15 | 0.53 |
| 2 | 0.53 | 0.53 | 6.15 | 6.15 | 6.15 | 0.53 | 6.15 | 0.53 |
| 3 | 0.53 | 0.53 | 6.15 | 6.15 | 6.15 | 0.53 | 6.15 | 0.53 |
| 4 | 0.53 | 0.53 | 6.15 | 6.15 | 6.15 | 0.53 | 6.15 | 0.53 |
| 5 | 0.53 | 0.53 | 6.15 | 6.15 | 6.15 | 0.53 | 6.15 | 0.53 |
| 6 | 0.53 | 0.53 | 6.15 | 6.15 | 6.15 | 0.53 | 6.15 | 0.53 |
| 7 | 0.53 | 0.53 | 6.15 | 6.15 | 6.15 | 0.53 | 6.15 | 0.53 |
| 8 | 0.53 | 1.69 | 7.31 | 6.15 | 6.15 | 1.69 | 7.31 | 0.53 |
| 9 | 1.69 | 2.94 | 8.56 | 7.31 | 7.31 | 2.94 | 8.56 | 1.69 |
| 10 | 2.94 | 4.09 | 9.71 | 8.56 | 8.56 | 4.09 | 9.71 | 2.94 |
| 11 | 4.09 | 4.09 | 9.71 | 9.71 | 9.71 | 4.09 | 9.71 | 4.09 |
| 12 | 4.09 | 4.09 | 9.71 | 9.71 | 9.71 | 4.09 | 9.71 | 4.09 |
| 13 | 4.09 | 4.09 | 9.71 | 9.71 | 9.71 | 4.09 | 9.71 | 4.09 |
| 14 | 4.09 | 4.09 | 9.71 | 9.71 | 9.71 | 4.09 | 9.71 | 4.09 |
| 15 | 4.09 | 4.09 | 9.71 | 9.71 | 9.71 | 4.09 | 9.71 | 4.09 |
| 16 | 4.09 | 4.09 | 9.71 | 9.71 | 9.71 | | | 4.09 |
| 17 | 4.09 | | | 9.71 | 9.71 | | | 4.09 |
| 18 | | | | 9.71 | 9.71 | | | |

# APPENDIX G: Input data of system validation

Input data used for the system validation for Factory 2 to 6 are given.

**Input data used for Factory 2**

Production volume and expected daily efficiency in Factory 2

| $t$ | $\tau$ | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | 797 | 929 | 929 | 929 | | |
| 2 | 874 | 1092 | | | | |
| 3 | 735 | 857 | | | | |
| 4 | 735 | 857 | 980 | | | |
| 5 | 407 | 475 | 543 | 611 | | |
| 6 | 570 | 665 | 760 | | | |
| 7 | 500 | 584 | 667 | | | |
| 8 | 687 | 687 | 801 | 916 | 687 | 801 |
| 9 | 767 | 895 | 895 | | | |
| 10 | 530 | 530 | | | | |
| 11 | 742 | 742 | 865 | 989 | | |
| 12 | 777 | 933 | 933 | 1088 | | |
| Efficiency ladder | 25% | 30% | 30% | 35% | 40% | 40% |

Machine types required for operations of part types in Factory 2

| n | t | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 1 | 1 | 1 | 12 | 12 | 1 | 14 | 14 | 1 | 12 | 14 | 1 | 1 |
| 2 | 1 | 1 | 1 | 1 | 7 | 2 | 2 | 1 | 1 | 14 | 1 | 1 |
| 3 | 3 | 3 | 14 | 1 | 2 | 1 | 2 | 3 | 1 | 2 | 9 | 3 |
| 4 | 2 | 1 | 2 | 1 | 2 | 9 | 1 | 7 | 1 | 2 | 1 | 7 |
| 5 | 4 | 2 | 2 | 6 | 9 | 2 | 9 | 2 | 6 | 3 | 9 | 2 |
| 6 | 5 | 4 | 1 | 3 | 3 | 14 | 2 | 1 | 3 | 3 | 10 | 1 |
| 7 | 11 | 11 | 3 | 2 | 7 | 8 | 14 | 3 | 2 | 9 | 2 | 3 |
| 8 | 3 | 11 | 2 | 1 | 2 | 1 | 8 | 9 | 1 | 9 | 11 | 9 |
| 9 | 13 | 9 | 1 | 6 | 3 | 1 | 1 | 3 | 6 | 1 | 3 | 3 |
| 10 | 14 | 14 | 6 | 3 | 7 | 9 | 1 | 6 | 3 | 1 | 9 | 11 |
| 11 | 14 | 14 | 5 | 2 | 2 | 3 | 9 | 11 | 2 | 9 | 14 | 3 |
| 12 |  | 14 | 14 | 11 | 14 | 9 | 3 | 3 | 11 | 14 | 14 | 13 |
| 13 |  |  | 11 | 14 | 14 | 11 | 9 | 13 | 14 | 9 |  | 13 |
| 14 |  |  | 14 | 14 | 3 | 11 | 11 | 13 | 14 | 9 |  | 14 |
| 15 |  |  | 14 |  | 3 | 9 | 11 | 14 |  | 2 |  | 14 |
| 16 |  |  | 14 |  | 3 | 13 | 9 | 14 |  | 9 |  |  |
| 17 |  |  |  |  | 11 | 14 | 13 |  |  | 9 |  |  |
| 18 |  |  |  |  | 9 | 14 | 14 |  |  | 2 |  |  |
| 19 |  |  |  |  | 3 |  | 14 |  |  | 3 |  |  |
| 20 |  |  |  |  | 14 |  |  |  |  | 3 |  |  |
| 21 |  |  |  |  | 14 |  |  |  |  | 9 |  |  |
| 22 |  |  |  |  |  |  |  |  |  | 11 |  |  |
| 23 |  |  |  |  |  |  |  |  |  | 9 |  |  |
| 24 |  |  |  |  |  |  |  |  |  | 14 |  |  |
| 25 |  |  |  |  |  |  |  |  |  | 14 |  |  |

Machine settings required for operations of part types in Factory 2

| $n$ | $t$ | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 1 | 4 | 6 | 12 | 12 | 2 | 14 | 14 | 3 | 12 | 14 | 7 | 7 |
| 2 | 1 | 7 | 5 | 6 | 3 | 4 | 5 | 6 | 3 | 14 | 1 | 2 |
| 3 | 1 | 2 | 14 | 7 | 1 | 7 | 4 | 2 | 8 | 7 | 5 | 3 |
| 4 | 7 | 6 | 3 | 2 | 5 | 8 | 4 | 3 | 3 | 2 | 5 | 1 |
| 5 | 5 | 4 | 3 | 1 | 5 | 4 | 2 | 5 | 6 | 5 | 4 | 5 |
| 6 | 1 | 9 | 1 | 12 | 5 | 14 | 6 | 8 | 6 | 1 | 1 | 6 |
| 7 | 2 | 3 | 2 | 4 | 2 | 1 | 14 | 8 | 3 | 1 | 1 | 7 |
| 8 | 6 | 1 | 6 | 5 | 1 | 7 | 4 | 5 | 1 | 2 | 1 | 8 |
| 9 | 12 | 8 | 2 | 3 | 1 | 1 | 2 | 1 | 1 | 1 | 3 | 11 |
| 10 | 14 | 14 | 5 | 2 | 3 | 4 | 5 | 3 | 2 | 1 | 4 | 8 |
| 11 | 14 | 14 | 12 | 8 | 7 | 2 | 5 | 5 | 6 | 2 | 14 | 9 |
| 12 | | 14 | 14 | 11 | 14 | 1 | 3 | 1 | 1 | 14 | 14 | 12 |
| 13 | | | 11 | 14 | 14 | 2 | 6 | 13 | 14 | 3 | | 12 |
| 14 | | | 14 | 14 | 4 | 2 | 2 | 13 | 14 | 3 | | 14 |
| 15 | | | 14 | | 1 | 2 | 3 | 14 | | 2 | | 14 |
| 16 | | | 14 | | 1 | 12 | 10 | 14 | | 4 | | |
| 17 | | | | | 1 | 14 | 12 | | | 4 | | |
| 18 | | | | | 5 | 14 | 14 | | | 7 | | |
| 19 | | | | | 12 | | 14 | | | 1 | | |
| 20 | | | | | 14 | | | | | 1 | | |
| 21 | | | | | 14 | | | | | 2 | | |
| 22 | | | | | | | | | | 2 | | |
| 23 | | | | | | | | | | 3 | | |
| 24 | | | | | | | | | | 14 | | |
| 25 | | | | | | | | | | 14 | | |

SMVs of respective operations of part types in Factory 2

| n | t | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 1 | 0.0696 | 0.2703 | 0.2400 | 0.2420 | 0.0673 | 0.2182 | 0.2182 | 0.0900 | 0.2420 | 0.2239 | 0.4719 | 0.0900 |
| 2 | 0.2425 | 0.7094 | 0.0673 | 0.0673 | 0.7328 | 0.1899 | 0.2734 | 0.2800 | 0.0673 | 0.2239 | 0.5071 | 0.2800 |
| 3 | 0.1904 | 0.2205 | 0.1210 | 0.2278 | 0.2428 | 0.2354 | 0.2030 | 0.2360 | 0.1527 | 0.1983 | 0.6563 | 0.2360 |
| 4 | 0.4080 | 0.2815 | 0.2847 | 0.5330 | 0.3560 | 0.3151 | 0.2354 | 0.4390 | 0.5330 | 0.1983 | 0.1545 | 0.4390 |
| 5 | 0.4925 | 0.2073 | 0.2329 | 0.6486 | 0.4232 | 0.1955 | 0.3151 | 0.3700 | 0.6947 | 0.1936 | 0.2194 | 0.4060 |
| 6 | 0.9930 | 0.1597 | 0.2840 | 0.1511 | 0.6405 | 0.2244 | 0.1966 | 0.3150 | 0.1511 | 0.1936 | 0.4039 | 0.3150 |
| 7 | 0.2145 | 0.2810 | 0.1973 | 0.1784 | 0.3625 | 0.7359 | 0.2244 | 0.1780 | 0.1674 | 0.4935 | 0.3919 | 0.1780 |
| 8 | 0.3492 | 0.1576 | 0.3962 | 0.2957 | 0.2370 | 0.4705 | 0.7359 | 0.3930 | 0.2957 | 0.5033 | 0.5174 | 0.3930 |
| 9 | 0.2014 | 0.1035 | 0.4377 | 0.3760 | 0.4017 | 0.3100 | 0.4602 | 0.2420 | 0.3760 | 0.1368 | 0.3492 | 0.2420 |
| 10 | 0.4046 | 0.4046 | 0.4159 | 0.2627 | 0.6457 | 0.2851 | 0.3100 | 0.4470 | 0.2627 | 0.3125 | 0.2310 | 0.2460 |
| 11 | 0.4095 | 0.3663 | 0.7700 | 0.1613 | 0.2044 | 0.2309 | 0.2851 | 0.2460 | 0.1502 | 0.3233 | 0.4046 | 0.1140 |
| 12 |  | 0.0529 | 0.1722 | 0.4167 | 0.0367 | 0.2310 | 0.2309 | 0.1140 | 0.4167 | 0.1156 | 0.4181 | 0.2640 |
| 13 |  |  | 0.2407 | 0.4046 | 0.1009 | 0.5209 | 0.2310 | 0.2640 | 0.4046 | 0.3846 |  | 0.2370 |
| 14 |  |  | 0.1620 | 0.2220 | 0.1775 | 0.1381 | 0.5209 | 0.2370 | 0.2220 | 0.3714 |  | 0.2100 |
| 15 |  |  | 0.4046 |  | 0.1695 | 0.1801 | 0.1381 | 0.4100 |  | 0.1835 |  | 0.2501 |
| 16 |  |  | 0.2220 |  | 0.3028 | 0.1907 | 0.1801 | 0.3500 |  | 0.3332 |  |  |
| 17 |  |  |  |  | 0.2892 | 0.4046 | 0.1907 |  |  | 0.3085 |  |  |
| 18 |  |  |  |  | 0.3837 | 0.3672 | 0.4046 |  |  | 0.1841 |  |  |
| 19 |  |  |  |  | 0.2140 |  | 0.3672 |  |  | 0.2548 |  |  |
| 20 |  |  |  |  | 0.4046 |  |  |  |  | 0.2309 |  |  |
| 21 |  |  |  |  | 0.2220 |  |  |  |  | 0.2310 |  |  |
| 22 |  |  |  |  |  |  |  |  |  | 0.4068 |  |  |
| 23 |  |  |  |  |  |  |  |  |  | 0.1385 |  |  |
| 24 |  |  |  |  |  |  |  |  |  | 0.4046 |  |  |

| 25 | | | | | | | | 0.1922 | | |
|----|--|--|--|--|--|--|--|--------|--|--|

Machine setup times for respective settings on each machine type in Factory 2

| $i$ | $l$ | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 1 | 5.48 | 1.23 | 0.89 | 1.34 | 0.94 | 0.85 | 0.85 | | | | | |
| 2 | 6.16 | 1.74 | 1.01 | 1.34 | 0.94 | 0.85 | 0.85 | | | | | |
| 3 | 0.81 | 0.47 | 1.50 | 0.98 | 0.88 | 0.64 | | 0.74 | 0.51 | 1.11 | 0.42 | |
| 4 | 5.46 | 1.42 | 1.02 | 1.21 | 0.82 | 0.65 | 1.98 | 0.98 | 1.78 | 1.45 | 0.42 | |
| 5 | 5.46 | 1.4 | 1.51 | 1.10 | 0.84 | 0.65 | 1.98 | 0.98 | 1.78 | 1.45 | 0.42 | |
| 6 | 5.46 | 1.38 | 1.32 | 0.97 | 0.86 | 0.65 | 1.98 | 0.98 | 1.78 | 1.45 | 0.42 | |
| 7 | 5.46 | 1.43 | 1.22 | 1.12 | 2.31 | 0.65 | 1.98 | 0.98 | 1.78 | 1.45 | 0.42 | |
| 8 | 0.81 | 0.47 | 1.08 | 1.02 | 0.88 | 0.64 | | 0.88 | 0.51 | 1.21 | 0.42 | |
| 9 | 0.81 | 0.47 | 1.23 | 0.74 | 0.88 | 0.64 | | 0.88 | 0.51 | 1.21 | 0.42 | |
| 10 | 9.12 | 1.88 | 1.05 | 1.00 | | 0.58 | 2.31 | 1.06 | 2.73 | 4.32 | | |
| 11 | 0.89 | 1.02 | 1.00 | 1.05 | | | | | | | 0.42 | |
| 12 | | | | | | | | | | | | 0.82 |
| 13 | | | | | | | | | | | | 0.56 |

Random numbers generated based on production downtimes in Factory 2

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 8.668 | 3.826 | 29.438 | 38.499 | 24.950 | 28.825 | 3.403 | 4.100 | 12.924 |
| 10.993 | 31.108 | 21.072 | 35.046 | 19.806 | 27.129 | 36.047 | 17.570 | 11.282 |
| 41.428 | 5.064 | 35.320 | 23.922 | 33.214 | 26.622 | 30.605 | 30.840 | 22.007 |
| 9.555 | 13.507 | 27.060 | 12.809 | 35.849 | 6.045 | 39.982 | 38.554 | 39.390 |
| 18.840 | 34.271 | 38.861 | 27.166 | 1.593 | 15.137 | 16.983 | 28.755 | 34.703 |
| 37.357 | 13.945 | 14.133 | 12.874 | 41.271 | 22.605 | 29.718 | 25.118 | 18.651 |
| 29.607 | 35.836 | 1.694 | 12.965 | 19.309 | 18.816 | 37.177 | 32.055 | 31.058 |
| 37.388 | 10.237 | 10.425 | 39.843 | 40.537 | 36.673 | 11.221 | 34.307 | 0.886 |
| 13.228 | 24.108 | 23.786 | 6.545 | 37.583 | 32.417 | 1.771 | 9.451 | 28.665 |
| 8.759 | 34.154 | 17.920 | 40.584 | 1.718 | 26.263 | 13.689 | 41.497 | 34.500 |
| 15.691 | 40.556 | 19.898 | 4.057 | 39.232 | 5.749 | 1.083 | 17.488 | 39.963 |
| 6.723 | 20.440 | 23.344 | 14.670 | 10.225 | 24.545 | 1.726 | 37.003 | 11.115 |
| 36.256 | 2.495 | 22.627 | 28.941 | 41.231 | 34.558 | 3.835 | 42.269 | 41.714 |
| 17.987 | 28.456 | 40.457 | 17.668 | 3.037 | 20.060 | 0.913 | 36.591 | 6.602 |
| 26.314 | 16.423 | 34.217 | 23.505 | 0.975 | 14.379 | 35.213 | 18.992 | 15.817 |
| 18.551 | 30.377 | 40.139 | 41.146 | 7.289 | 41.511 | 22.048 | 31.284 | 3.304 |
| 17.714 | 23.141 | 33.377 | 24.119 | 6.848 | 36.371 | 14.510 | 26.861 | 16.905 |
| 9.365 | 14.879 | 28.269 | 38.741 | 34.943 | 38.189 | 10.254 | 3.108 | 3.923 |
| 25.654 | 37.763 | 1.240 | 3.376 | 25.885 | 20.066 | 40.495 | 5.659 | 31.148 |

Number of available machines of each type in Factory 2

| $i$ | Total number of available machines |
| --- | --- |
| 1 | 46 |
| 2 | 40 |
| 3 | 40 |
| 4 | 18 |
| 5 | 27 |
| 6 | 23 |
| 7 | 21 |
| 8 | 23 |
| 9 | 39 |
| 10 | 19 |
| 11 | 36 |
| 12 | 18 |
| 13 | 23 |
| 14 | 46 |

**Input data used for Factory 3**

Production volume and expected daily efficiency in Factory 3

| $t$ | $\tau$ | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | 455 | 546 | 546 | 637 | 728 | |
| 2 | 523 | 627 | 627 | 732 | 836 | |
| 3 | 473 | 567 | 567 | 662 | | |
| 4 | 597 | 716 | 716 | | | |
| 5 | 734 | 880 | 880 | 1027 | | |
| 6 | 710 | 852 | 852 | 994 | | |
| 7 | 571 | 685 | 685 | 799 | 914 | |
| 8 | 412 | 494 | 494 | 577 | 659 | 742 |
| 9 | 527 | 632 | 632 | 737 | 843 | |
| 10 | 637 | 764 | 764 | 891 | | |
| 11 | 1275 | 1529 | | | | |
| 12 | 373 | 447 | 447 | 522 | | |
| 13 | 529 | 635 | 635 | 740 | | |
| 14 | 375 | 450 | 450 | 525 | | |
| 15 | 418 | 502 | 502 | 586 | 669 | |
| 16 | 604 | 724 | 724 | 845 | 966 | |
| 17 | 589 | 706 | 706 | 824 | 942 | |
| 18 | 620 | 744 | 744 | 868 | 992 | |
| 19 | 910 | 1091 | 1091 | | | |
| 20 | 779 | 935 | 935 | 1091 | | |
| 21 | 546 | 656 | 656 | 765 | 874 | |
| 22 | 396 | 475 | 475 | 554 | 634 | 713 |
| 23 | 468 | 561 | 561 | 655 | 748 | 842 |
| Efficiency ladder | 25% | 30% | 30% | 35% | 40% | 45% |

Machine types required for operations of part types in Factory 3

| $n$ | $t$ | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
| 1 | 13 | 7 | 1 | 13 | 11 | 1 | 15 | 8 | 13 | 15 | 13 | 3 | 13 | 2 | 13 | 9 | 1 | 3 | 13 | 11 | 3 | 11 | 14 |
| 2 | 2 | 3 | 14 | 15 | 14 | 8 | 6 | 15 | 6 | 10 | 4 | 4 | 3 | 12 | 2 | 15 | 1 | 3 | 15 | 15 | 1 | 13 | 15 |
| 3 | 5 | 3 | 15 | 4 | 3 | 3 | 4 | 7 | 3 | 6 | 15 | 14 | 9 | 4 | 7 | 14 | 5 | 5 | 2 | 1 | 4 | 7 | 12 |
| 4 | 6 | 13 | 3 | 1 | 9 | 10 | 10 | 13 | 15 | 3 | 5 | 10 | 2 | 3 | 4 | 9 | 9 | 9 | 7 | 7 | 13 | 3 | 10 |
| 5 | 9 | 9 | 1 | 8 | 13 | 4 | 8 | 3 | 9 | 11 | 2 | 12 | 8 | 13 | 4 | 8 | 9 | 14 | 10 | 3 | 7 | 8 | 7 |
| 6 | 10 | 4 | 6 | 9 | 15 | 5 | 3 | 3 | 11 | 10 | 10 | 12 | 9 | 1 | 15 | 1 | 3 | 4 | 15 | 6 | 12 | 12 | 4 |
| 7 | 4 | 14 | 8 | 7 | 3 | 9 | 15 | 9 | 11 | 15 | 11 | 1 | 4 | 15 | 1 | 7 | 7 | 4 | 5 | 6 | 6 | 11 | 13 |
| 8 | 6 | 13 | 13 | 5 | 4 | 5 | 5 | 8 | 7 | 14 | 15 | 13 | 6 | 14 | 10 | 2 | 4 | 11 | 12 | 3 | 6 | 7 | 1 |
| 9 | 11 | 13 | 3 | 10 | 15 | 1 | 9 | 14 | 5 | 1 | 15 | 9 | 15 | 9 | 10 | 6 | 9 | 8 | 11 | 2 | 1 | 14 | 9 |
| 10 | 12 | 15 | 9 | 11 | 15 | 1 | 3 | 15 | 12 | 7 |  | 10 | 10 | 4 | 11 | 13 | 9 | 2 | 11 | 15 | 14 | 10 | 3 |
| 11 | 12 | 10 | 1 | 15 |  | 9 | 11 | 3 | 12 | 15 |  | 9 | 12 | 6 | 11 | 15 | 10 | 15 | 6 | 15 | 10 | 10 | 9 |
| 12 | 15 | 7 | 11 | 15 |  | 10 | 14 | 12 | 9 | 15 |  | 9 | 8 | 1 | 8 | 15 | 14 | 7 | 14 |  | 8 | 6 | 9 |
| 13 | 3 | 15 | 11 |  |  | 14 | 15 | 4 | 11 |  |  | 11 | 14 | 9 | 8 |  | 15 | 3 | 15 |  | 12 | 15 | 15 |
| 14 | 2 | 15 | 4 |  |  | 15 | 15 | 5 | 11 |  |  | 14 | 15 | 8 | 9 |  | 15 | 14 | 15 |  | 12 | 15 | 9 |
| 15 | 3 |  | 3 |  |  | 15 |  | 2 | 12 |  |  | 9 | 15 | 12 | 10 |  |  | 15 |  |  | 15 |  | 15 |
| 16 | 9 |  | 8 |  |  |  |  | 3 | 14 |  |  | 11 |  | 14 | 14 |  |  | 15 |  |  | 15 |  | 14 |
| 17 | 15 |  | 11 |  |  |  |  | 6 | 15 |  |  | 9 |  | 14 | 15 |  |  |  |  |  |  |  | 5 |
| 18 | 15 |  | 12 |  |  |  |  | 15 | 15 |  |  | 13 |  | 9 | 15 |  |  |  |  |  |  |  | 1 |
| 19 |  |  | 15 |  |  |  |  | 15 |  |  |  | 15 |  | 15 |  |  |  |  |  |  |  |  | 15 |
| 20 |  |  | 15 |  |  |  |  |  |  |  |  | 15 |  | 15 |  |  |  |  |  |  |  |  | 15 |

Machine settings required for operations of part types in Factory 3

| $n$ | $t$ | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
| 1 | 13 | 8 | 10 | 13 | 11 | 9 | 15 | 5 | 13 | 15 | 11 | 3 | 13 | 2 | 13 | 9 | 8 | 8 | 13 | 11 | 3 | 11 | 11 |
| 2 | 5 | 1 | 11 | 15 | 11 | 3 | 7 | 15 | 8 | 10 | 2 | 3 | 7 | 1 | 8 | 15 | 1 | 4 | 15 | 15 | 5 | 11 | 15 |
| 3 | 9 | 3 | 15 | 8 | 4 | 8 | 4 | 6 | 6 | 9 | 15 | 11 | 5 | 5 | 8 | 11 | 9 | 7 | 8 | 9 | 1 | 6 | 6 |
| 4 | 6 | 11 | 1 | 9 | 6 | 3 | 2 | 11 | 15 | 3 | 4 | 10 | 7 | 4 | 7 | 9 | 3 | 2 | 4 | 10 | 11 | 6 | 10 |
| 5 | 6 | 2 | 7 | 8 | 11 | 6 | 3 | 2 | 8 | 11 | 2 | 12 | 1 | 11 | 4 | 8 | 7 | 14 | 4 | 1 | 7 | 10 | 7 |
| 6 | 5 | 5 | 2 | 6 | 15 | 7 | 4 | 6 | 8 | 3 | 10 | 3 | 6 | 8 | 15 | 1 | 1 | 1 | 15 | 6 | 12 | 2 | 4 |
| 7 | 7 | 11 | 8 | 8 | 1 | 6 | 15 | 9 | 5 | 15 | 11 | 1 | 3 | 15 | 3 | 7 | 7 | 7 | 1 | 4 | 2 | 11 | 11 |
| 8 | 1 | 11 | 11 | 7 | 4 | 4 | 5 | 8 | 5 | 11 | 15 | 11 | 1 | 11 | 6 | 2 | 1 | 5 | 7 | 2 | 9 | 10 | 5 |
| 9 | 3 | 11 | 4 | 2 | 15 | 4 | 2 | 11 | 7 | 4 | 15 | 9 | 15 | 9 | 5 | 6 | 2 | 3 | 3 | 2 | 1 | 11 | 9 |
| 10 | 5 | 15 | 1 | 3 | 15 | 2 | 4 | 15 | 1 | 10 | | 10 | 2 | 5 | 1 | 11 | 7 | 2 | 6 | 15 | 11 | 10 | 3 |
| 11 | 9 | 4 | 1 | 15 | | 9 | 4 | 3 | 6 | 15 | | 9 | 8 | 2 | 8 | 15 | 8 | 15 | 2 | 15 | 5 | 10 | 10 |
| 12 | 15 | 8 | 4 | 15 | | 6 | 14 | 12 | 9 | 15 | | 9 | 5 | 9 | 6 | 15 | 14 | 5 | 14 | | 9 | 4 | 9 |
| 13 | 7 | 15 | 11 | | | 14 | 15 | 4 | 5 | | | 11 | 14 | 9 | 5 | | 15 | 4 | 15 | | 4 | 15 | 15 |
| 14 | 9 | 15 | 4 | | | 15 | 15 | 5 | 8 | | | 11 | 15 | 8 | 8 | | 15 | 14 | 15 | | 6 | 15 | 9 |
| 15 | 3 | | 1 | | | 15 | | 6 | 9 | | | 9 | 15 | 12 | 6 | | | 15 | | | 15 | | 15 |
| 16 | 4 | | 5 | | | | | 3 | 14 | | | 11 | | 11 | 14 | | | 15 | | | 15 | | 11 |
| 17 | 15 | | 11 | | | | | 5 | 15 | | | 9 | | 11 | 15 | | | | | | | | 5 |
| 18 | 15 | | 12 | | | | | 15 | 15 | | | 11 | | 9 | 15 | | | | | | | | 6 |
| 19 | | | 15 | | | | | 15 | | | | 15 | | 15 | | | | | | | | | 15 |
| 20 | | | 15 | | | | | | | | | 15 | | 15 | | | | | | | | | 15 |

SMVs of respective operations of part types in Factory 3

| $n$ | $t$ | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 1 | 0.1800 | 0.4981 | 0.1253 | 0.1443 | 0.4217 | 0.0228 | 0.6617 | 0.1918 | 0.1992 | 0.5728 | 0.4874 | 0.4544 |
| 2 | 0.5096 | 0.2339 | 0.1612 | 0.1746 | 0.4533 | 0.4932 | 0.3722 | 0.5254 | 0.1305 | 0.5984 | 0.0030 | 0.1535 |
| 3 | 0.4855 | 0.3466 | 0.4482 | 0.5998 | 0.3298 | 0.1821 | 0.1917 | 0.2952 | 0.3957 | 0.3982 | 0.3508 | 0.1861 |
| 4 | 0.3407 | 0.0052 | 0.2474 | 0.2437 | 0.4493 | 0.0314 | 0.4698 | 0.5369 | 0.6004 | 0.5768 | 0.4589 | 0.6828 |
| 5 | 0.1360 | 0.6328 | 0.3212 | 0.6601 | 0.4704 | 0.4695 | 0.0191 | 0.1668 | 0.3042 | 0.4557 | 0.3545 | 0.3116 |
| 6 | 0.4638 | 0.3730 | 0.0077 | 0.5535 | 0.4348 | 0.6634 | 0.4898 | 0.5432 | 0.5710 | 0.3986 | 0.2135 | 0.1063 |
| 7 | 0.6607 | 0.5625 | 0.4460 | 0.5545 | 0.3169 | 0.1670 | 0.3005 | 0.3576 | 0.4936 | 0.4837 | 0.1094 | 0.3230 |
| 8 | 0.4756 | 0.4261 | 0.3481 | 0.2688 | 0.0355 | 0.0364 | 0.1205 | 0.3225 | 0.1132 | 0.0285 | 0.2750 | 0.0628 |
| 9 | 0.2408 | 0.2303 | 0.5112 | 0.0368 | 0.5389 | 0.5051 | 0.2648 | 0.4632 | 0.3741 | 0.4025 | 0.0073 | 0.6128 |
| 10 | 0.2400 | 0.1503 | 0.0543 | 0.6157 | 0.4758 | 0.1493 | 0.6251 | 0.2941 | 0.0830 | 0.1144 | | 0.3202 |
| 11 | 0.2042 | 0.6424 | 0.4549 | 0.6534 | | 0.1722 | 0.5375 | 0.0519 | 0.0113 | 0.2628 | | 0.0928 |
| 12 | 0.2484 | 0.2249 | 0.1791 | 0.3194 | | 0.6190 | 0.3580 | 0.3640 | 0.1169 | 0.2308 | | 0.1376 |
| 13 | 0.2387 | 0.5725 | 0.0519 | | | 0.2620 | 0.5129 | 0.2829 | 0.2482 | | | 0.3338 |
| 14 | 0.5485 | 0.6094 | 0.5445 | | | 0.2380 | 0.1202 | 0.4777 | 0.3625 | | | 0.4105 |
| 15 | 0.3185 | | 0.2173 | | | 0.0429 | | 0.4286 | 0.6647 | | | 0.6613 |
| 16 | 0.2220 | | 0.6596 | | | | | 0.6184 | 0.1722 | | | 0.7450 |
| 17 | 0.4420 | | 0.5595 | | | | | 0.4599 | 0.3549 | | | 0.6255 |
| 18 | 0.3755 | | 0.1126 | | | | | 0.3709 | 0.2712 | | | 0.6768 |
| 19 | | | 0.0983 | | | | | 0.2410 | | | | 0.1235 |
| 20 | | | 0.5476 | | | | | | | | | 0.7058 |

SMVs of respective operations of part types in Factory 3 continued

| n | t | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
| 2 | 0.4816 | 0.0850 | 0.6217 | 0.3278 | 0.4788 | 0.2102 | 0.2063 | 0.1254 | 0.1923 | 0.4734 | 0.3542 |
| 3 | 0.2703 | 0.1506 | 0.0612 | 0.6609 | 0.4177 | 0.6497 | 0.6013 | 0.3050 | 0.2404 | 0.2387 | 0.0566 |
| 4 | 0.3707 | 0.5350 | 0.6087 | 0.3516 | 0.2194 | 0.1479 | 0.1213 | 0.0693 | 0.1745 | 0.1568 | 0.5522 |
| 5 | 0.7260 | 0.6595 | 0.6237 | 0.4665 | 0.5730 | 0.7222 | 0.4782 | 0.1624 | 0.0114 | 0.7026 | 0.0372 |
| 6 | 0.1718 | 0.7406 | 0.0895 | 0.5969 | 0.0367 | 0.4194 | 0.0370 | 0.7083 | 0.2098 | 0.0892 | 0.2126 |
| 7 | 0.6394 | 0.2882 | 0.5127 | 0.2637 | 0.2319 | 0.5567 | 0.1233 | 0.3754 | 0.1532 | 0.4805 | 0.6076 |
| 8 | 0.6577 | 0.2608 | 0.7086 | 0.2208 | 0.3368 | 0.5900 | 0.0695 | 0.3366 | 0.0470 | 0.5556 | 0.5017 |
| 9 | 0.4037 | 0.0183 | 0.4843 | 0.6150 | 0.1121 | 0.4891 | 0.1286 | 0.1514 | 0.6105 | 0.3465 | 0.1598 |
| 10 | 0.4451 | 0.5851 | 0.0667 | 0.3366 | 0.2434 | 0.4994 | 0.5003 | 0.1492 | 0.1660 | 0.6012 | 0.1845 |
| 11 | 0.2025 | 0.4858 | 0.1870 | 0.2498 | 0.3547 | 0.1576 | 0.3884 | 0.6114 | 0.1301 | 0.4260 | 0.6868 |
| 12 | 0.2340 | 0.2513 | 0.1672 | 0.2496 | 0.1367 | 0.0058 | 0.7038 | 0.1721 | 0.2916 | 0.4272 | 0.4590 |
| 13 | 0.3870 | 0.6731 | 0.1066 | 0.4340 | 0.6483 | 0.0682 | 0.3478 | | 0.0885 | 0.3572 | 0.1677 |
| 14 | 0.3016 | 0.4312 | 0.2637 | | 0.6229 | 0.1593 | 0.6838 | | 0.4803 | 0.3869 | 0.5728 |
| 15 | 0.0989 | 0.6355 | 0.0848 | | 0.4809 | 0.3249 | 0.2582 | | 0.6359 | 0.0315 | 0.4275 |
| 16 | 0.0564 | 0.7239 | 0.4044 | | | 0.6316 | | | 0.2145 | | 0.5727 |
| 17 | | 0.2123 | 0.5148 | | | 0.5282 | | | 0.0503 | | 0.4700 |
| 18 | | 0.5295 | 0.7459 | | | | | | | | 0.1478 |
| 19 | | 0.1545 | 0.6336 | | | | | | | | 0.5907 |
| 20 | | 0.0121 | | | | | | | | | 0.0076 |
| 21 | | 0.2518 | | | | | | | | | 0.5022 |

Machine setup times for respective settings on each machine type in Factory 3

| $i$ | $l$ | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 1 | 0.92 | 1.58 | 0.75 | 1.44 | 0.65 | 0.93 | 1.77 | 1.03 | 1.65 | 1.22 | |
| 2 | 0.84 | 1.01 | 0.85 | 2.86 | 0.93 | 0.85 | 5.34 | | | | |
| 3 | 6.18 | 0.98 | 0.85 | 1.02 | | 0.59 | 9.02 | | | | |
| 4 | 5.46 | 1.33 | 0.59 | 1.08 | 0.99 | 1.40 | | 0.43 | 0.90 | 0.98 | |
| 5 | 1.36 | 0.81 | 0.53 | 1.03 | 1.02 | 1.33 | | 3.37 | 0.53 | 1.59 | |
| 6 | 0.72 | 0.95 | 0.48 | 1.02 | 1.01 | 0.92 | 0.98 | 1.78 | 0.48 | 1.48 | |
| 7 | 8.79 | 1.12 | 0.97 | | 0.87 | 0.84 | 0.98 | 1.78 | 1.04 | 1.64 | |
| 8 | 1.40 | 0.76 | 0.88 | | 0.98 | 1.02 | 0.98 | 1.78 | 0.65 | 1.66 | |
| 9 | 1.33 | 1.19 | 0.78 | 1.15 | 0.78 | 1.08 | 0.88 | 0.51 | 0.93 | 1.56 | |
| 10 | 0.83 | 1.13 | 1.03 | 1.03 | 0.59 | | 0.88 | 0.51 | 1.21 | 1.32 | |
| 11 | 1.16 | 1.04 | 0.74 | 1.26 | 0.85 | | 1.01 | 1.33 | 0.34 | 1.90 | |
| 12 | 0.41 | 0.93 | 0.85 | 1.03 | 0.98 | 1.04 | 0.93 | 1.03 | 1.02 | 1.85 | |
| 13 | 1.61 | 1.47 | 0.85 | 0.99 | 0.88 | 0.93 | | 4.83 | 1.03 | 1.60 | |
| 14 | | | | | | | | | | | 0.63 |

Random numbers generated based on production downtimes in Factory 3

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 29.148 | 16.813 | 19.512 | 31.478 | 12.403 | 6.946 | 5.994 | 11.276 | 23.375 |
| 25.097 | 25.062 | 19.627 | 33.914 | 29.368 | 29.054 | 3.552 | 19.861 | 3.139 |
| 32.247 | 8.676 | 23.288 | 22.303 | 3.865 | 3.955 | 26.310 | 12.805 | 21.771 |
| 31.189 | 7.607 | 23.109 | 10.201 | 18.451 | 14.864 | 6.585 | 5.061 | 20.609 |
| 14.789 | 0.269 | 21.661 | 3.348 | 32.821 | 17.762 | 16.090 | 33.613 | 33.789 |
| 13.080 | 19.104 | 5.824 | 24.996 | 15.430 | 9.233 | 15.915 | 29.305 | 18.480 |
| 33.355 | 3.134 | 12.883 | 12.950 | 2.987 | 33.588 | 29.890 | 18.133 | 9.486 |
| 7.818 | 17.916 | 14.563 | 2.585 | 1.035 | 33.650 | 16.611 | 13.810 | 31.938 |
| 11.389 | 21.645 | 15.886 | 23.484 | 33.714 | 18.604 | 33.153 | 24.909 | 15.599 |
| 8.872 | 12.880 | 20.692 | 17.424 | 10.586 | 29.083 | 30.098 | 19.158 | 10.677 |
| 14.382 | 18.313 | 4.172 | 4.574 | 31.337 | 15.015 | 4.176 | 5.734 | 17.652 |
| 8.124 | 20.797 | 14.597 | 5.720 | 15.528 | 0.631 | 33.420 | 16.453 | 15.561 |
| 3.417 | 13.590 | 9.448 | 10.268 | 0.912 | 17.006 | 19.111 | 9.077 | 26.805 |
| 3.356 | 25.893 | 14.418 | 5.016 | 15.094 | 25.469 | 21.346 | 19.024 | 15.903 |
| 32.991 | 25.875 | 7.093 | 22.650 | 17.806 | 20.008 | 9.361 | 27.006 | 25.565 |
| 31.736 | 2.719 | 7.453 | 27.479 | 26.521 | 4.442 | 2.981 | 4.992 | 5.083 |
| 20.692 | 20.705 | 29.867 | 10.280 | 2.906 | 5.103 | 16.534 | 32.052 | 4.221 |
| 26.430 | 1.734 | 10.316 | 25.828 | 2.602 | 24.042 | 21.316 | 28.295 | 8.056 |
| 21.086 | 21.890 | 13.108 | 15.149 | 11.318 | 10.403 | 26.145 | 20.932 | 22.538 |
| 0.135 | 15.301 | 13.103 | 16.499 | 9.553 | 33.607 | 19.827 | 31.757 | 29.941 |
| 0.157 | 8.673 | 2.324 | 33.938 | 32.869 | 1.898 | 13.551 | 22.397 | 5.002 |
| 3.734 | 11.172 | 4.866 | 21.143 | 6.564 | 7.195 | 9.173 | 1.807 | 7.423 |
| 16.892 | 25.928 | 23.065 | 0.312 | 11.860 | 26.121 | 9.118 | 28.016 | 11.705 |
| 19.196 | 18.823 | 31.392 | 32.086 | 1.064 | 6.100 | 20.256 | 25.194 | 17.235 |
| 32.290 | 9.870 | 21.233 | 22.543 | 9.479 | 27.519 | 8.103 | 19.409 | 25.493 |

Number of available machines of each type in Factory 3

| $i$ | Total number of available machines |
|---|---|
| 1 | 12 |
| 2 | 13 |
| 3 | 26 |
| 4 | 25 |
| 5 | 17 |
| 6 | 27 |
| 7 | 20 |
| 8 | 19 |
| 9 | 36 |
| 10 | 19 |
| 11 | 27 |
| 12 | 17 |
| 13 | 25 |
| 14 | 21 |
| 15 | 59 |

**Input data used for Factory 4**

Production volume and expected daily efficiency in Factory 4

| t | τ | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| 1 | 435 | 521 | 521 | 608 |
| 2 | 500 | 600 | 600 | 700 |
| 3 | 543 | 651 | 651 | 760 |
| 4 | 583 | 699 | 699 | 816 |
| 5 | 897 | 1077 | | |
| 6 | 434 | 521 | 521 | 608 |
| 7 | 721 | 865 | | |
| 8 | 696 | 835 | 835 | |
| 9 | 711 | 853 | 853 | |
| 10 | 501 | 601 | 601 | |
| 11 | 598 | 718 | 718 | |
| 12 | 596 | 716 | 716 | 835 |
| 13 | 639 | 767 | 767 | |
| 14 | 581 | 697 | 697 | 813 |
| 15 | 826 | 991 | 991 | 1156 |
| 16 | 674 | 809 | 809 | 944 |
| 17 | 866 | 1039 | 1039 | |
| 18 | 1209 | 1451 | | |
| 19 | 762 | 915 | | |
| 20 | 662 | 794 | 794 | 926 |
| 21 | 1070 | 1284 | 1284 | |
| 22 | 869 | 1043 | 1043 | |
| 23 | 1003 | 1204 | 1204 | |
| 24 | 732 | 878 | 878 | 1024 |
| 25 | 786 | 944 | 944 | 1101 |
| 26 | 804 | 965 | 965 | 1125 |
| 27 | 895 | 1074 | 1074 | |
| 28 | 1034 | 1240 | 1240 | |
| Efficiency ladder | 25% | 30% | 30% | 35% |

Machine types required for operations of part types in Factory 4

| $n$ | $t$ | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 1 | 11 | 12 | 3 | 10 | 2 | 3 | 12 | 1 | 8 | 2 | 6 | 8 | 1 | 7 | 8 | 4 | 7 | 11 | 9 | 9 | 6 | 11 | 4 | 11 | 6 | 6 | 11 | 3 |
| 2 | 5 | 7 | 4 | 4 | 4 | 10 | 6 | 12 | 2 | 11 | 7 | 11 | 8 | 1 | 7 | 6 | 9 | 3 | 2 | 12 | 12 | 1 | 2 | 6 | 2 | 5 | 1 | 9 |
| 3 | 4 | 5 | 6 | 3 | 2 | 10 | 1 | 10 | 6 | 7 | 11 | 6 | 4 | 8 | 5 | 10 | 9 | 1 | 8 | 10 | 7 | 7 | 8 | 12 | 8 | 4 | 8 | 12 |
| 4 | 5 | 2 | 10 | 1 | 9 | 3 | 1 | 9 | 1 | 8 | 3 | 1 | 10 | 2 | 2 | 6 | 8 | 1 | 7 | 10 | 6 | 9 | 1 | 3 | 10 | 10 | 5 | 7 |
| 5 | 6 | 6 | 11 | 11 | 11 | 12 | 8 | 6 | 12 | 2 | 1 | 9 | 2 | 5 | 12 | 1 | 2 | 5 | 9 | 3 | 2 | 1 | 5 | 9 | 1 | 2 | 12 | 4 |
| 6 | 8 | 6 | 2 | 4 | 3 | 11 | 3 | 11 | 3 | 9 | 12 | 9 | 8 | 9 | 11 | 6 | 11 | 2 | 11 | 7 | 10 | 3 | 11 | 5 | 2 | 9 | 8 | 8 |
| 7 | 2 | 9 | 2 | 7 | 4 | 7 | 11 | 8 | 12 | 5 | 5 | 11 | 6 | 12 | 8 | 5 | 6 | 1 | 5 | 11 | 12 | 6 | 1 | 11 | 9 | 12 | 3 | 10 |
| 8 | 5 | 7 | 9 | 12 | 12 | 12 | 12 | 7 | 8 | 7 | 3 | 5 | 12 | 8 | 4 | 4 | 11 | 8 | 11 | 8 | 12 | 10 | 5 | 1 | 10 | 5 | 1 | 10 |
| 9 | 3 | 7 | 7 | 5 | 5 | 9 | 12 | 4 | 12 | 12 | 2 | 6 | 12 | 12 | 7 | 12 | 12 | 4 | 1 | 10 | 2 | 9 | 3 | 8 | 11 | 3 | 8 | 2 |
| 10 | 8 | 2 | 12 | 12 | 12 | 10 | | 9 | 12 | 12 | 12 | 3 | 12 | 12 | 3 | 7 | 3 | 10 | 11 | 7 | 7 | 1 | 12 | 8 | 7 | 6 | 9 | 12 |
| 11 | 6 | 6 | 12 | 5 | 12 | 10 | | 12 | | | 12 | 1 | | 12 | 11 | 11 | 12 | 9 | 12 | 7 | 12 | 9 | 9 | 2 | 13 | 3 | 12 | 12 |
| 12 | 12 | 11 | | 12 | | 11 | | 12 | | | 12 | 12 | | | 12 | 10 | 12 | 6 | 12 | 3 | 12 | 11 | 1 | 10 | 12 | 12 | 12 | 12 |
| 13 | 12 | 9 | | 12 | | 2 | | | | | | 12 | | | 12 | 6 | | 12 | | 12 | | 12 | 12 | 12 | | 12 | | |
| 14 | | 12 | | | | 12 | | | | | | | | | | 12 | | 12 | | 12 | | 12 | 12 | 12 | | | | |
| 15 | | 12 | | | | 12 | | | | | | | | | | 12 | | | | 12 | | | | | | | | |

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Machine settings required for operations of part types in Factory 4

| n | t | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 1 | 10 | 12 | 4 | 10 | 4 | 3 | 12 | 8 | 8 | 2 | 1 | 8 | 1 | 6 | 11 | 3 | 10 | 7 | 3 | 3 | 7 | 3 | 4 | 4 | 4 | 6 | 7 | 10 |
| 2 | 5 | 1 | 4 | 1 | 1 | 10 | 3 | 12 | 1 | 10 | 1 | 10 | 5 | 5 | 11 | 5 | 11 | 8 | 5 | 12 | 7 | 12 | 2 | 2 | 6 | 5 | 2 | 8 |
| 3 | 1 | 2 | 1 | 4 | 4 | 10 | 1 | 10 | 3 | 2 | 10 | 6 | 6 | 7 | 11 | 2 | 5 | 6 | 9 | 6 | 2 | 10 | 2 | 10 | 10 | 10 | 4 | 7 |
| 4 | 5 | 2 | 10 | 1 | 9 | 3 | 1 | 1 | 3 | 8 | 3 | 6 | 10 | 7 | 10 | 6 | 7 | 12 | 5 | 9 | 3 | 6 | 7 | 5 | 7 | 10 | 6 | 8 |
| 5 | 1 | 2 | 10 | 10 | 10 | 12 | 8 | 6 | 12 | 2 | 9 | 2 | 5 | 5 | 8 | 9 | 10 | 12 | 10 | 9 | 4 | 6 | 10 | 9 | 7 | 9 | 12 | 10 |
| 6 | 8 | 4 | 3 | 1 | 3 | 10 | 1 | 10 | 1 | 8 | 12 | 2 | 8 | 7 | 5 | 3 | 5 | 6 | 11 | 12 | 4 | 2 | 5 | 7 | 11 | 7 | 8 | 5 |
| 7 | 4 | 7 | 2 | 2 | 6 | 6 | 10 | 9 | 12 | 4 | 3 | 10 | 1 | 12 | 5 | 11 | 7 | 3 | 7 | 4 | 12 | 5 | 7 | 11 | 11 | 4 | 2 | 10 |
| 8 | 3 | 3 | 7 | 12 | 12 | 12 | 12 | 5 | 9 | 3 | 1 | 2 | 12 | 8 | 7 | 2 | 4 | 6 | 1 | 12 | 3 | 12 | 3 | 9 | 1 | 8 | 8 | 4 |
| 9 | 3 | 8 | 3 | 2 | 1 | 5 | 12 | 4 | 12 | 12 | 3 | 3 | 12 | 12 | 1 | 6 | 10 | 8 | 11 | 6 | 9 | 12 | 1 | 11 | 1 | 4 | 7 | 3 |
| 10 | 8 | 2 | 12 | 12 | 12 | 10 | | 4 | 12 | 12 | 12 | 2 | 12 | 12 | 12 | 7 | 8 | 4 | 3 | 12 | 11 | 7 | 2 | 9 | 3 | 9 | 10 | 11 |
| 11 | 2 | 4 | 12 | 6 | 12 | 10 | | 12 | | | 12 | 6 | | 12 | 1 | 5 | 6 | 5 | 5 | 7 | 1 | 2 | 4 | 3 | 10 | 9 | 1 | 11 |
| 12 | 12 | 10 | | 12 | | 10 | | 12 | | | 12 | 12 | | | 11 | 5 | 1 | 6 | 4 | 4 | 3 | 10 | 4 | 12 | 2 | 7 | 12 | 3 |
| 13 | 12 | 9 | | 12 | | 2 | | | | | 12 | | | | 6 | 8 | | 10 | | 9 | | 9 | 4 | 10 | | 5 | 10 | 9 |
| 14 | | 12 | | | | 12 | | | | | | | | | | 5 | | 9 | | 3 | | 3 | 6 | 12 | | | 9 | 7 |
| 15 | | 12 | | | | 12 | | | | | | | | | | 2 | | | | 9 | | | | | | | | |

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SMVs of respective operations of part types in Factory 4

| n | t | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 1 | 0.6736 | 0.2064 | 0.7267 | 0.6066 | 0.1069 | 0.5124 | 0.2268 | 0.4451 | 0.5800 | 0.2369 | 0.4796 | 0.0209 | 0.2127 | 0.3420 |
| 2 | 0.7669 | 0.0423 | 0.5907 | 0.1962 | 0.3841 | 0.7008 | 0.7584 | 0.3476 | 0.4150 | 0.3404 | 0.6990 | 0.2407 | 0.4987 | 0.6826 |
| 3 | 0.5592 | 0.4821 | 0.1574 | 0.1884 | 0.2527 | 0.5420 | 0.7440 | 0.3537 | 0.4583 | 0.0004 | 0.2483 | 0.5219 | 0.0101 | 0.3390 |
| 4 | 0.4916 | 0.1829 | 0.4370 | 0.3221 | 0.5050 | 0.2750 | 0.0613 | 0.2409 | 0.6108 | 0.4796 | 0.6962 | 0.4455 | 0.7625 | 0.6146 |
| 5 | 0.2010 | 0.3288 | 0.2529 | 0.2096 | 0.3041 | 0.2560 | 0.0097 | 0.1328 | 0.2049 | 0.0866 | 0.6516 | 0.2655 | 0.5099 | 0.3034 |
| 6 | 0.5880 | 0.6751 | 0.6144 | 0.5646 | 0.2553 | 0.1312 | 0.6605 | 0.5119 | 0.1589 | 0.4903 | 0.3893 | 0.2876 | 0.7484 | 0.3463 |
| 7 | 0.5769 | 0.3716 | 0.5185 | 0.1731 | 0.2574 | 0.3030 | 0.0671 | 0.0302 | 0.1014 | 0.7143 | 0.5779 | 0.3556 | 0.3989 | 0.0439 |
| 8 | 0.0393 | 0.3887 | 0.4033 | 0.6174 | 0.0942 | 0.5416 | 0.6605 | 0.6522 | 0.3477 | 0.0653 | 0.4551 | 0.1424 | 0.1104 | 0.6623 |
| 9 | 0.6834 | 0.1486 | 0.2278 | 0.0447 | 0.0062 | 0.2762 | 0.5399 | 0.2886 | 0.2110 | 0.3227 | 0.4758 | 0.7013 | 0.5778 | 0.0579 |
| 10 | 0.1085 | 0.7328 | 0.4836 | 0.4096 | 0.1560 | 0.2660 | | 0.4098 | 0.6959 | 0.2298 | 0.2823 | 0.2827 | 0.6784 | 0.4719 |
| 11 | 0.6325 | 0.4695 | 0.5411 | 0.6040 | 0.6737 | 0.3771 | | 0.2569 | | | 0.0378 | 0.4926 | | 0.3435 |
| 12 | 0.1059 | 0.1799 | | 0.6293 | | 0.1984 | | 0.1940 | | | 0.3714 | 0.4840 | | |
| 13 | 0.7578 | 0.3651 | | 0.0461 | | 0.6750 | | | | | | 0.2524 | | |
| 14 | | 0.7462 | | | | 0.4205 | | | | | | | | |
| 15 | | 0.0521 | | | | 0.7139 | | | | | | | | |

SMVs of respective operations of part types in Factory 4 continued

| $n$ | $t$ | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 1 | 0.3482 | 0.0832 | 0.4396 | 0.1999 | 0.1217 | 0.2200 | 0.2074 | 0.0780 | 0.2470 | 0.0936 | 0.4522 | 0.0972 | 0.2941 | 0.0249 |
| 2 | 0.1293 | 0.2929 | 0.0561 | 0.1563 | 0.1379 | 0.3421 | 0.2389 | 0.1656 | 0.4554 | 0.0516 | 0.0577 | 0.2557 | 0.1529 | 0.0191 |
| 3 | 0.2869 | 0.1979 | 0.2746 | 0.2607 | 0.2674 | 0.0046 | 0.0102 | 0.3978 | 0.0882 | 0.0716 | 0.2274 | 0.3858 | 0.0154 | 0.0505 |
| 4 | 0.0373 | 0.2848 | 0.0128 | 0.3406 | 0.3862 | 0.3004 | 0.1507 | 0.4289 | 0.0843 | 0.3165 | 0.3255 | 0.4152 | 0.4367 | 0.0761 |
| 5 | 0.4314 | 0.3646 | 0.4486 | 0.1633 | 0.4524 | 0.4131 | 0.4041 | 0.1707 | 0.3323 | 0.2063 | 0.0149 | 0.2799 | 0.3404 | 0.2169 |
| 6 | 0.1585 | 0.4386 | 0.3910 | 0.1305 | 0.1958 | 0.3463 | 0.1902 | 0.3978 | 0.0070 | 0.2098 | 0.3377 | 0.0301 | 0.0097 | 0.1500 |
| 7 | 0.3787 | 0.3438 | 0.1182 | 0.3405 | 0.3393 | 0.4199 | 0.2031 | 0.1153 | 0.2746 | 0.2656 | 0.1362 | 0.0450 | 0.2888 | 0.4433 |
| 8 | 0.3611 | 0.2041 | 0.0208 | 0.2387 | 0.0494 | 0.1577 | 0.0937 | 0.1181 | 0.3905 | 0.3628 | 0.2210 | 0.0312 | 0.1460 | 0.1085 |
| 9 | 0.3830 | 0.2493 | 0.2864 | 0.0687 | 0.3879 | 0.2928 | 0.0665 | 0.1533 | 0.1831 | 0.3486 | 0.3870 | 0.3148 | 0.4080 | 0.3310 |
| 10 | 0.0951 | 0.3300 | 0.1627 | 0.0581 | 0.1078 | 0.3804 | 0.2799 | 0.2713 | 0.1851 | 0.4097 | 0.2768 | 0.4522 | 0.3279 | 0.4140 |
| 11 | 0.1643 | 0.1285 | 0.0751 | 0.0643 | 0.1309 | 0.0117 | 0.2809 | 0.0060 | 0.0269 | 0.3188 | 0.3363 | 0.2118 | 0.1585 | 0.2121 |
| 12 | 0.1893 | 0.2599 | 0.3748 | 0.1820 | 0.4461 | 0.3701 | 0.0282 | 0.1671 | 0.0872 | 0.1775 | 0.1574 | 0.3346 | 0.1513 | 0.0545 |
| 13 | 0.0590 | 0.3651 | | 0.0168 | | 0.2866 | | 0.3403 | 0.0019 | 0.4309 | | 0.2524 | 0.1040 | 0.3708 |
| 14 | | 0.3651 | | 0.0029 | | 0.3526 | | 0.2840 | 0.3167 | 0.4101 | | | 0.1701 | 0.1295 |
| 15 | | 0.3651 | | | | 0.4538 | | | | | | | | |

Machine setup times for respective settings on each machine type in Factory 4

| $i$ | $l$ | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 1 | 0.48 | 1.08 | 1.40 | 1.01 | 3.37 | 1.36 | 5.34 | 1.05 | 0.83 | |
| 2 | 0.97 | 1.03 | 1.33 | 0.98 | 1.78 | 0.72 | 9.02 | | | |
| 3 | 7.08 | 1.02 | 0.92 | 1.33 | | 0.59 | 9.02 | | | |
| 4 | 5.46 | 1.33 | 0.59 | 1.08 | 0.99 | 1.40 | | 0.43 | 0.90 | |
| 5 | 1.03 | 1.02 | 1.40 | 1.03 | 1.78 | 1.33 | | 3.37 | 0.53 | |
| 6 | 0.85 | 1.08 | 1.33 | 1.02 | 1.78 | 0.92 | | 1.78 | 0.48 | |
| 7 | 0.59 | 1.03 | 0.97 | | 0.87 | 0.84 | | 1.78 | 1.04 | |
| 8 | 1.40 | 0.76 | 0.88 | | 0.98 | 1.02 | 0.98 | 1.78 | 0.65 | |
| 9 | 1.03 | 1.19 | 0.78 | 1.15 | 0.78 | 1.08 | 0.88 | 0.51 | 0.93 | |
| 10 | | | | | | | | | | 0.63 |
| 11 | | | | | | | | | | 0.62 |

Random numbers generated based on production downtimes in Factory 4

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 18.112 | 21.958 | 3.983 | 2.166 | 6.183 | 9.577 | 18.182 | 13.557 | 12.959 |
| 21.726 | 17.866 | 19.823 | 18.773 | 16.029 | 3.114 | 10.805 | 14.061 | 4.055 |
| 16.896 | 12.317 | 21.316 | 19.613 | 5.199 | 1.961 | 6.462 | 1.793 | 12.440 |
| 4.155 | 10.852 | 14.667 | 15.797 | 12.414 | 1.270 | 19.947 | 2.016 | 15.609 |
| 8.294 | 14.048 | 18.126 | 0.856 | 2.049 | 23.797 | 23.086 | 20.726 | 11.714 |
| 16.976 | 2.144 | 15.415 | 24.943 | 3.784 | 8.307 | 17.816 | 5.901 | 12.553 |
| 4.988 | 22.489 | 9.596 | 10.069 | 23.136 | 17.736 | 13.388 | 9.623 | 15.147 |
| 12.812 | 16.747 | 20.590 | 0.488 | 11.877 | 1.678 | 8.752 | 17.099 | 16.598 |
| 7.370 | 0.423 | 7.497 | 14.181 | 7.276 | 6.768 | 3.244 | 11.561 | 20.300 |
| 19.562 | 5.462 | 9.784 | 6.563 | 8.395 | 14.014 | 18.438 | 10.943 | 24.056 |
| 14.379 | 5.404 | 21.355 | 15.893 | 25.395 | 16.279 | 16.638 | 7.605 | 1.643 |
| 4.067 | 9.002 | 17.772 | 21.227 | 0.080 | 10.232 | 23.724 | 12.172 | 13.921 |
| 7.958 | 15.464 | 0.830 | 0.232 | 4.486 | 20.830 | 3.141 | 23.770 | 3.309 |
| 9.941 | 16.760 | 1.919 | 17.817 | 7.587 | 14.082 | 12.630 | 8.215 | 1.111 |
| 23.446 | 8.010 | 18.975 | 0.113 | 4.853 | 14.573 | 6.260 | 19.649 | 25.570 |
| 3.815 | 24.172 | 16.877 | 11.968 | 14.698 | 19.022 | 17.997 | 15.878 | 24.401 |
| 14.011 | 0.686 | 1.096 | 22.638 | 3.351 | 8.350 | 16.001 | 0.703 | 4.024 |
| 2.578 | 16.558 | 18.928 | 2.266 | 4.138 | 8.259 | 9.746 | 15.065 | 5.950 |
| 10.951 | 15.159 | 19.658 | 13.135 | 8.274 | 11.185 | 17.302 | 6.159 | 13.134 |

Number of available machines of each type in Factory 4

| $i$ | Total number of available machines |
|---|---|
| 1 | 18 |
| 2 | 32 |
| 3 | 29 |
| 4 | 24 |
| 5 | 27 |
| 6 | 22 |
| 7 | 24 |
| 8 | 23 |
| 9 | 21 |
| 10 | 20 |
| 11 | 23 |
| 12 | 57 |

**Input data used for Factory 5**

Production volume and expected daily efficiency in Factory 5

| t | τ | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| 1 | 523 | 628 | 733 | |
| 2 | 993 | 1191 | | |
| 3 | 988 | 1186 | | |
| 4 | 857 | 1028 | 1199 | |
| 5 | 712 | 855 | 997 | |
| 6 | 885 | 1062 | | |
| 7 | 710 | 851 | 993 | |
| 8 | 692 | 830 | 968 | |
| 9 | 710 | 852 | 994 | 1136 |
| 10 | 637 | 764 | 891 | |
| 11 | 735 | 882 | 1029 | 1176 |
| 12 | 867 | 1040 | 1214 | |
| 13 | 1264 | 1516 | | |
| 14 | 957 | 1148 | 1339 | |
| 15 | 1011 | 1214 | 1416 | |
| 16 | 884 | 1061 | 1238 | |
| 17 | 1362 | 1634 | | |
| 18 | 870 | 1044 | 1218 | |
| 19 | 1038 | 1245 | | |
| 20 | 870 | 1044 | 1218 | |
| 21 | 933 | 1119 | 1306 | |
| Efficiency ladder | 25% | 30% | 35% | 40% |

Machine types required for operations of part types in Factory 5

| n | t | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 1 | 11 | 5 | 1 | 9 | 1 | 13 | 10 | 6 | 15 | 14 | 10 | 5 | 13 | 15 | 1 | 8 | 12 | 6 | 2 | 3 | 7 |
| 2 | 11 | 7 | 7 | 9 | 15 | 2 | 6 | 8 | 13 | 10 | 3 | 6 | 9 | 1 | 10 | 11 | 6 | 14 | 6 | 4 | 11 |
| 3 | 11 | 10 | 2 | 2 | 8 | 7 | 10 | 9 | 8 | 6 | 7 | 13 | 10 | 6 | 7 | 2 | 8 | 5 | 7 | 8 | 5 |
| 4 | 8 | 3 | 11 | 1 | 6 | 8 | 10 | 13 | 8 | 13 | 3 | 4 | 8 | 1 | 15 | 1 | 1 | 4 | 12 | 10 | 7 |
| 5 | 14 | 4 | 11 | 11 | 8 | 3 | 10 | 7 | 8 | 1 | 15 | 11 | 13 | 13 | 6 | 2 | 4 | 3 | 1 | 6 | 4 |
| 6 | 11 | 14 | 14 | 12 | 12 | 3 | 11 | 1 | 1 | 14 | 11 | 1 | 13 | 13 | 13 | 12 | 11 | 7 | 12 | 8 | 6 |
| 7 | 15 | 10 | 5 | 7 | 4 | 2 | 8 | 12 | 10 | 8 | 1 | 10 | 15 | 15 | 8 | 4 | 7 | 14 | 2 | 4 | 14 |
| 8 | 15 | 1 | 2 | 9 | 11 | 11 | 12 | 13 | 9 | 11 | 5 | 3 | 14 | 5 | 15 | 12 | 12 | 14 | 15 | 3 | 14 |
| 9 | 7 | 15 | 15 | 6 | 12 | 5 | 11 | 12 | 5 | 5 | 14 | 3 | 10 | 8 | 2 | 13 | 9 | 2 | 13 | 9 | 5 |
| 10 | 13 | 15 | 15 | 15 | 13 | 15 | 2 | 3 | 9 | 15 | 9 | 13 | 9 | 9 | 5 | 7 | 7 | 9 | 5 | 15 | 5 |
| 11 | 2 |  |  | 15 | 2 | 15 | 3 | 9 | 10 | 15 | 15 | 13 | 15 | 15 | 15 | 11 | 15 | 7 | 15 | 13 | 15 |
| 12 | 15 |  |  |  | 13 |  | 15 | 5 | 9 |  | 15 | 15 | 15 | 15 | 15 | 7 | 15 | 15 | 10 | 12 | 15 |
| 13 | 15 |  |  |  | 7 |  | 15 | 11 | 15 |  |  | 15 |  |  |  | 15 |  | 15 | 15 | 15 |  |
| 14 |  |  |  |  | 12 |  |  | 15 | 1 |  |  |  |  |  |  | 15 |  |  | 15 | 15 |  |
| 15 |  |  |  |  | 15 |  |  | 15 | 15 |  |  |  |  |  |  |  |  |  |  |  |  |
| 16 |  |  |  |  | 9 |  |  |  | 15 |  |  |  |  |  |  |  |  |  |  |  |  |
| 17 |  |  |  |  | 15 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 18 |  |  |  |  | 15 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

Machine settings required for operations of part types in Factory 5

| n | t | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 1 | 2 | 8 | 7 | 2 | 7 | 11 | 2 | 3 | 10 | 11 | 8 | 9 | 7 | 15 | 2 | 7 | 9 | 3 | 5 | 9 | 2 |
| 2 | 3 | 3 | 7 | 7 | 9 | 9 | 6 | 1 | 11 | 8 | 6 | 3 | 9 | 1 | 3 | 10 | 4 | 7 | 8 | 7 | 10 |
| 3 | 10 | 8 | 7 | 10 | 4 | 9 | 3 | 4 | 8 | 7 | 4 | 1 | 4 | 4 | 9 | 4 | 7 | 2 | 8 | 4 | 9 |
| 4 | 9 | 8 | 9 | 3 | 2 | 2 | 3 | 11 | 8 | 1 | 2 | 4 | 4 | 3 | 7 | 5 | 10 | 1 | 8 | 3 | 9 |
| 5 | 11 | 4 | 5 | 8 | 5 | 10 | 1 | 7 | 8 | 1 | 5 | 10 | 6 | 3 | 2 | 8 | 7 | 8 | 7 | 3 | 8 |
| 6 | 11 | 11 | 11 | 8 | 12 | 4 | 8 | 1 | 1 | 8 | 10 | 6 | 6 | 3 | 1 | 8 | 6 | 1 | 2 | 5 | 8 |
| 7 | 15 | 2 | 7 | 5 | 3 | 8 | 8 | 12 | 10 | 8 | 7 | 9 | 15 | 15 | 4 | 4 | 7 | 10 | 2 | 4 | 10 |
| 8 | 15 | 9 | 10 | 8 | 3 | 3 | 4 | 11 | 9 | 2 | 9 | 6 | 10 | 8 | 15 | 4 | 12 | 10 | 15 | 3 | 10 |
| 9 | 2 | 15 | 15 | 3 | 3 | 4 | 1 | 10 | 9 | 3 | 11 | 7 | 8 | 10 | 7 | 2 | 1 | 7 | 1 | 8 | 9 |
| 10 | 11 | 15 | 15 | 15 | 11 | 15 | 5 | 4 | 10 | 3 | 9 | 1 | 4 | 4 | 4 | 2 | 10 | 5 | 1 | 15 | 1 |
| 11 | 2 |  |  | 15 | 2 | 15 | 5 | 4 | 5 | 6 | 15 | 7 | 15 | 15 | 15 | 9 | 15 | 4 | 15 | 13 | 15 |
| 12 | 15 |  |  |  | 13 |  | 15 | 7 | 3 |  | 15 | 15 | 15 | 15 | 15 | 6 | 15 | 15 | 10 | 8 | 15 |
| 13 | 15 |  |  |  | 7 |  | 15 | 11 | 15 |  |  | 15 |  |  |  | 15 |  | 15 | 15 | 15 |  |
| 14 |  |  |  |  | 12 |  |  | 15 | 4 |  |  |  |  |  |  |  |  |  |  |  |  |
| 15 |  |  |  |  | 15 |  |  | 15 | 15 |  |  |  |  |  |  |  |  |  |  |  |  |
| 16 |  |  |  |  | 9 |  |  |  | 15 |  |  |  |  |  |  |  |  |  |  |  |  |
| 17 |  |  |  |  | 15 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 18 |  |  |  |  | 15 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

SMVs of respective operations of part types in Factory 5

| n | t | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 1 | 0.2630 | 0.3140 | 0.0973 | 0.5202 | 0.3338 | 0.4996 | 0.5499 | 0.4539 | 0.4884 | 0.3573 | 0.5573 | 0.1578 | 0.0850 | 0.0685 |
| 2 | 0.5068 | 0.0905 | 0.3589 | 0.4870 | 0.3952 | 0.3980 | 0.1071 | 0.0694 | 0.3907 | 0.5664 | 0.1504 | 0.2381 | 0.2993 | 0.2541 |
| 3 | 0.5565 | 0.4795 | 0.4957 | 0.5196 | 0.2082 | 0.2318 | 0.2417 | 0.2460 | 0.0340 | 0.4986 | 0.1009 | 0.3212 | 0.1021 | 0.2424 |
| 4 | 0.4878 | 0.1922 | 0.3840 | 0.2242 | 0.2870 | 0.5479 | 0.1949 | 0.3765 | 0.4350 | 0.1379 | 0.0243 | 0.3322 | 0.1390 | 0.1581 |
| 5 | 0.5340 | 0.3782 | 0.1342 | 0.5129 | 0.5254 | 0.1331 | 0.3309 | 0.2312 | 0.1002 | 0.2843 | 0.4456 | 0.0181 | 0.1356 | 0.2092 |
| 6 | 0.2471 | 0.0281 | 0.1087 | 0.2996 | 0.1971 | 0.0345 | 0.1251 | 0.1783 | 0.2872 | 0.4062 | 0.2355 | 0.3109 | 0.1896 | 0.2058 |
| 7 | 0.2893 | 0.4883 | 0.0041 | 0.1315 | 0.0139 | 0.2303 | 0.0665 | 0.3647 | 0.5619 | 0.3219 | 0.3583 | 0.1887 | 0.2461 | 0.1675 |
| 8 | 0.4925 | 0.2756 | 0.4365 | 0.2855 | 0.5011 | 0.3173 | 0.1362 | 0.0987 | 0.1170 | 0.4419 | 0.1760 | 0.1715 | 0.0422 | 0.2358 |
| 9 | 0.4748 | 0.5161 | 0.4837 | 0.0924 | 0.0882 | 0.2318 | 0.1047 | 0.2520 | 0.0078 | 0.3410 | 0.5628 | 0.1821 | 0.2640 | 0.0423 |
| 10 | 0.4599 | 0.1380 | 0.4117 | 0.0801 | 0.2658 | 0.4928 | 0.4675 | 0.2141 | 0.1835 | 0.1769 | 0.5541 | 0.3260 | 0.1134 | 0.2686 |
| 11 | 0.5608 | | | 0.2090 | 0.0158 | 0.1381 | 0.4621 | 0.2020 | 0.3494 | 0.5255 | 0.2829 | 0.0452 | 0.1045 | 0.2049 |
| 12 | 0.1238 | | | | 0.0441 | | 0.1115 | 0.5398 | 0.2035 | | 0.4708 | 0.0785 | 0.1027 | 0.3516 |
| 13 | 0.5089 | | | | 0.2578 | | 0.5157 | 0.4468 | 0.2175 | | | 0.5089 | | |
| 14 | | | | | 0.0576 | | | 0.0783 | 0.3577 | | | | | |
| 15 | | | | | 0.2409 | | | 0.3076 | 0.2457 | | | | | |
| 16 | | | | | 0.2422 | | | | 0.1857 | | | | | |
| 17 | | | | | 0.1508 | | | | | | | | | |
| 18 | | | | | 0.2187 | | | | | | | | | |

SMVs of respective operations of part types in Factory 5 continued

| $n$ | $t$ | | | | | | |
|---|---|---|---|---|---|---|---|
|  | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 1 | 0.1404 | 0.3300 | 0.2883 | 0.2501 | 0.1122 | 0.1424 | 0.2066 |
| 2 | 0.1290 | 0.3165 | 0.1550 | 0.0474 | 0.1370 | 0.2289 | 0.1619 |
| 3 | 0.1983 | 0.1436 | 0.0219 | 0.1201 | 0.1907 | 0.2956 | 0.2708 |
| 4 | 0.2541 | 0.1012 | 0.2172 | 0.1481 | 0.2617 | 0.2886 | 0.1948 |
| 5 | 0.0191 | 0.3501 | 0.0841 | 0.0997 | 0.0590 | 0.1315 | 0.3129 |
| 6 | 0.1183 | 0.1358 | 0.2622 | 0.0412 | 0.0412 | 0.1440 | 0.2207 |
| 7 | 0.2843 | 0.2621 | 0.0349 | 0.2679 | 0.2395 | 0.2899 | 0.1220 |
| 8 | 0.1269 | 0.2481 | 0.2768 | 0.3216 | 0.2226 | 0.1607 | 0.2357 |
| 9 | 0.3049 | 0.1929 | 0.0000 | 0.3378 | 0.3248 | 0.1663 | 0.0569 |
| 10 | 0.3558 | 0.1764 | 0.0039 | 0.1326 | 0.1030 | 0.0030 | 0.3250 |
| 11 | 0.0726 | 0.3143 | 0.2191 | 0.2926 | 0.3343 | 0.3299 | 0.3354 |
| 12 | 0.2747 | 0.1547 | 0.1283 | 0.2945 | 0.0399 | 0.3343 | 0.0273 |
| 13 |  | 0.2578 |  | 0.5157 | 0.4468 | 0.2175 |  |
| 14 |  | 0.0576 |  |  | 0.0783 | 0.3577 |  |

Machine setup times for respective settings on each machine type in Factory 5

| $i$ | $l$ | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 1 | 0.40 | 0.65 | 0.48 | 1.00 | 1.02 | 1.63 | 0.99 | 0.58 | 1.35 | 0.98 |  |
| 2 | 1.55 | 1.92 | 0.57 | 1.68 | 0.95 | 1.61 | 0.87 | 0.67 | 0.55 | 0.96 |  |
| 3 | 1.42 | 1.16 | 0.34 | 1.11 | 1.21 | 1.53 | 0.51 | 0.65 | 0.51 | 0.51 |  |
| 4 | 5.84 | 0.66 | 0.64 | 1.46 | 0.97 | 1.02 | 0.75 | 0.78 | 0.53 | 1.54 |  |
| 5 | 6.22 | 0.97 | 0.81 | 2.03 | 1.59 | 2.11 | 0.99 | 0.98 | 0.92 | 0.95 |  |
| 6 | 1.39 | 0.67 | 0.73 | 1.36 | 1.64 | 1.06 | 0.41 | 0.76 | 0.46 | 0.95 |  |
| 7 | 1.72 | 1.91 | 0.44 | 2.00 | 0.99 | 1.20 | 0.43 | 0.75 | 0.54 | 0.76 |  |
| 8 | 1.37 | 0.41 | 0.43 | 2.10 | 1.92 | 1.90 | 0.58 | 0.79 | 0.74 | 1.82 |  |
| 9 | 0.83 | 1.02 | 0.59 | 1.34 | 1.01 | 1.20 | 0.63 | 1.11 | 0.72 | 1.69 |  |
| 10 | 2.05 | 1.20 | 0.61 | 1.60 | 1.12 | 1.46 | 0.89 | 0.75 | 0.82 | 0.66 |  |
| 11 | 0.98 | 1.21 | 0.57 | 1.68 | 1.01 | 1.40 | 0.41 | 0.92 | 0.87 | 0.85 |  |
| 12 | 1.55 | 0.41 | 0.61 | 1.33 | 1.18 | 1.06 | 0.41 | 0.32 | 0.85 | 0.91 |  |
| 13 | 1.55 | 0.41 | 0.61 | 1.33 | 1.18 | 1.06 | 0.41 | 0.32 | 0.85 |  |  |
| 14 |  |  |  |  |  |  |  |  |  |  | 0.71 |

Random numbers generated based on production downtimes in Factory 5

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 12.459 | 35.025 | 19.796 | 27.340 | 10.276 | 42.837 | 31.938 | 40.272 | 12.413 |
| 13.681 | 14.108 | 39.737 | 34.017 | 23.645 | 2.452 | 40.456 | 18.841 | 10.870 |
| 5.057 | 11.111 | 14.478 | 19.787 | 33.323 | 30.288 | 30.367 | 32.428 | 36.315 |
| 12.522 | 20.886 | 20.714 | 29.138 | 30.935 | 24.373 | 15.962 | 0.274 | 1.099 |
| 14.938 | 35.574 | 18.704 | 19.718 | 42.751 | 29.152 | 28.572 | 1.163 | 12.211 |
| 7.552 | 42.049 | 21.171 | 7.097 | 30.262 | 31.860 | 34.359 | 17.869 | 29.733 |
| 41.924 | 40.185 | 23.109 | 35.591 | 2.608 | 18.452 | 0.845 | 21.035 | 26.986 |
| 38.811 | 27.307 | 9.255 | 3.008 | 4.930 | 20.851 | 6.304 | 17.051 | 1.545 |
| 7.707 | 17.178 | 26.424 | 40.276 | 14.560 | 26.340 | 38.877 | 21.883 | 8.142 |
| 7.770 | 2.147 | 0.471 | 22.873 | 39.635 | 8.021 | 22.468 | 16.150 | 39.957 |
| 19.551 | 35.693 | 33.180 | 15.259 | 20.189 | 0.932 | 0.537 | 40.790 | 26.560 |
| 13.315 | 39.354 | 15.060 | 11.884 | 42.228 | 7.643 | 28.502 | 33.429 | 17.464 |
| 36.474 | 40.060 | 13.088 | 11.087 | 6.268 | 19.909 | 6.815 | 20.603 | 8.041 |
| 13.783 | 22.848 | 4.097 | 22.769 | 6.225 | 9.221 | 38.480 | 35.856 | 4.506 |
| 6.986 | 14.514 | 17.910 | 29.068 | 33.579 | 1.280 | 8.475 | 16.871 | 14.933 |
| 41.905 | 26.294 | 12.907 | 14.659 | 38.133 | 33.797 | 24.483 | 24.924 | 31.593 |
| 41.717 | 12.951 | 33.541 | 29.550 | 31.592 | 21.576 | 40.342 | 17.297 | 42.458 |
| 9.545 | 24.080 | 1.553 | 42.439 | 11.977 | 26.482 | 15.289 | 16.808 | 27.774 |
| 20.659 | 8.709 | 0.795 | 34.597 | 38.335 | 24.184 | 19.081 | 20.810 | 13.613 |

Number of available machines of each type in Factory 5

| $i$ | Total number of available machines |
|---|---|
| 1 | 17 |
| 2 | 25 |
| 3 | 21 |
| 4 | 16 |
| 5 | 20 |
| 6 | 19 |
| 7 | 15 |
| 8 | 18 |
| 9 | 26 |
| 10 | 31 |
| 11 | 32 |
| 12 | 21 |
| 13 | 24 |
| 14 | 17 |
| 15 | 45 |

## Input data used for Factory 6

Production volume and expected daily efficiency in Factory 6

| t | τ | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| 1 | 465 | 558 | 651 | 744 | |
| 2 | 666 | 799 | 932 | | |
| 3 | 531 | 638 | 744 | 850 | |
| 4 | 618 | 742 | | | |
| 5 | 508 | 609 | 711 | | |
| 6 | 583 | 700 | 817 | 933 | |
| 7 | 662 | 794 | 927 | 1059 | |
| 8 | 732 | 878 | 1024 | | |
| 9 | 862 | 1034 | 1206 | | |
| 10 | 666 | 799 | 932 | | |
| 11 | 479 | 575 | 670 | 766 | 862 |
| 12 | 969 | 1163 | | | |
| 13 | 989 | 1187 | 1385 | | |
| 14 | 1077 | 1292 | | | |
| 15 | 818 | 981 | 1145 | | |
| 16 | 925 | 1110 | 1295 | | |
| 17 | 1101 | 1322 | | | |
| 18 | 1067 | 1280 | 1493 | | |
| 19 | 975 | 1170 | 1365 | | |
| 20 | 1247 | 1497 | | | |
| 21 | 997 | 1196 | 1395 | | |
| Efficiency ladder | 25% | 30% | 35% | 40% | 45% |

Machine types required for operations of part types in Factory 6

| n | t | | | | | | | | | | | | | | | | | | | | |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 1 | 1 | 14 | 14 | 2 | 3 | 14 | 14 | 16 | 10 | 4 | 14 | 12 | 1 | 13 | 7 | 13 | 12 | 1 | 11 | 16 | 1 |
| 2 | 2 | 10 | 5 | 5 | 5 | 6 | 3 | 6 | 5 | 15 | 6 | 4 | 14 | 5 | 3 | 4 | 5 | 15 | 15 | 4 | 8 |
| 3 | 5 | 9 | 2 | 5 | 2 | 6 | 1 | 3 | 15 | 6 | 4 | 6 | 9 | 6 | 8 | 13 | 7 | 16 | 7 | 15 | 14 |
| 4 | 7 | 4 | 3 | 7 | 10 | 2 | 8 | 10 | 16 | 12 | 9 | 14 | 11 | 1 | 11 | 11 | 2 | 15 | 9 | 14 | 7 |
| 5 | 11 | 7 | 4 | 4 | 8 | 13 | 7 | 7 | 9 | 9 | 11 | 6 | 15 | 12 | 1 | 10 | 7 | 2 | 3 | 9 | 4 |
| 6 | 6 | 14 | 8 | 4 | 16 | 5 | 1 | 6 | 14 | 13 | 16 | 8 | 8 | 15 | 7 | 1 | 13 | 4 | 10 | 7 | 3 |
| 7 | 12 | 7 | 10 | 16 | 16 | 10 | 11 | 6 | 4 | 5 | 12 | 9 | 10 | 6 | 15 | 5 | 2 | 12 | 6 | 10 | 12 |
| 8 | 16 | 11 | 2 | 11 | 9 | 5 | 7 | 6 | 5 | 16 | 11 | 12 | 15 | 1 | 3 | 14 | 1 | 8 | 13 | 7 | 2 |
| 9 | 16 | 4 | 11 | 11 | 1 | 1 | 8 | 12 | 9 | 1 | 11 | 3 | 3 | 16 | 12 | 2 | 12 | 10 | 5 | 4 | 2 |
| 10 | 3 | 5 | 9 | 12 | 11 | 3 | 16 | 1 | 13 | 4 | 10 | 10 | 7 | 12 | 5 | 10 | 6 | 8 | 10 | 15 | 8 |
| 11 | 4 | 16 | 13 | 9 | 4 | 4 | 16 | 1 | 16 | 4 | 5 | 13 | 14 | 16 | 15 | 4 | 9 | 16 | 11 | 7 | 2 |
| 12 | 10 | 15 | 1 | 6 | 12 | 4 | | 5 | 16 | 8 | 7 | 16 | 4 | 3 | 6 | 4 | 6 | 4 | 16 | 4 | 16 |
| 13 | 3 | 16 | 15 | 3 | 11 | 11 | | 16 | | 16 | 10 | 16 | 12 | 14 | 4 | 16 | 12 | 1 | 16 | 16 | 16 |
| 14 | 15 | 16 | 16 | 10 | 13 | 12 | | 16 | | 16 | 16 | | 1 | 16 | 16 | 3 | 13 | 7 | | 16 | |
| 15 | 16 | | 16 | 16 | 16 | 16 | | | | | 16 | | 16 | 16 | 16 | 16 | 16 | 16 | | | |
| 16 | 16 | | | 16 | 16 | 16 | | | | | | | 16 | | | 16 | 16 | 16 | | | |

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Machine settings required for operations of part types in Factory 6

| n | t | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 1 | 3 | 10 | 14 | 6 | 5 | 14 | 10 | 16 | 6 | 6 | 14 | 7 | 2 | 11 | 9 | 10 | 5 | 5 | 6 | 16 | 1 |
| 2 | 9 | 7 | 6 | 6 | 5 | 1 | 9 | 9 | 7 | 10 | 9 | 4 | 14 | 2 | 8 | 12 | 11 | 15 | 15 | 4 | 8 |
| 3 | 3 | 1 | 9 | 1 | 9 | 16 | 8 | 9 | 10 | 5 | 9 | 2 | 4 | 12 | 3 | 12 | 1 | 16 | 2 | 15 | 14 |
| 4 | 8 | 1 | 2 | 1 | 6 | 1 | 8 | 7 | 16 | 3 | 8 | 10 | 8 | 6 | 1 | 1 | 8 | 15 | 3 | 14 | 1 |
| 5 | 6 | 9 | 1 | 2 | 7 | 5 | 5 | 5 | 9 | 5 | 8 | 8 | 15 | 8 | 3 | 4 | 9 | 4 | 11 | 9 | 2 |
| 6 | 8 | 10 | 3 | 1 | 4 | 1 | 1 | 9 | 10 | 8 | 16 | 4 | 11 | 15 | 4 | 3 | 10 | 1 | 9 | 12 | 8 |
| 7 | 1 | 1 | 2 | 16 | 16 | 8 | 5 | 5 | 6 | 7 | 4 | 9 | 6 | 10 | 15 | 5 | 6 | 11 | 12 | 12 | 12 |
| 8 | 16 | 9 | 6 | 6 | 6 | 9 | 4 | 5 | 7 | 16 | 3 | 7 | 15 | 3 | 8 | 14 | 5 | 2 | 7 | 7 | 10 |
| 9 | 16 | 2 | 3 | 6 | 2 | 9 | 9 | 8 | 4 | 3 | 8 | 4 | 2 | 16 | 5 | 11 | 3 | 8 | 9 | 4 | 8 |
| 10 | 1 | 3 | 2 | 8 | 2 | 5 | 16 | 5 | 4 | 7 | 6 | 7 | 12 | 12 | 11 | 12 | 5 | 4 | 8 | 15 | 2 |
| 11 | 9 | 16 | 7 | 3 | 5 | 3 | 16 | 4 | 16 | 7 | 5 | 6 | 14 | 16 | 3 | 8 | 6 | 16 | 10 | 6 | 3 |
| 12 | 2 | 10 | 1 | 5 | 2 | 7 |  | 2 | 16 | 3 | 8 | 16 | 6 | 11 | 10 | 11 | 1 | 1 | 16 | 5 | 16 |
| 13 | 8 | 16 | 15 | 2 | 7 | 3 |  | 16 |  | 16 | 7 | 16 | 12 | 14 | 8 | 16 | 5 | 1 | 16 | 16 | 16 |
| 14 | 15 | 16 | 16 | 9 | 6 | 7 |  | 16 |  | 16 | 16 |  | 3 | 16 | 16 | 3 | 10 | 9 |  | 16 |  |
| 15 | 16 |  | 16 | 16 | 16 | 16 |  |  |  |  | 16 |  | 16 | 16 | 16 | 16 | 16 | 16 |  |  |  |
| 16 | 16 |  |  | 16 | 16 | 16 |  |  |  |  |  |  | 16 |  |  | 16 | 16 | 16 |  |  |  |

SMVs of respective operations of part types in Factory 6

| $n$ | $t$ | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 1 | 0.2832 | 0.4640 | 0.4246 | 0.5370 | 0.0389 | 0.1314 | 0.4574 | 0.0013 | 0.1988 | 0.3520 | 0.5167 | 0.4520 | 0.1570 | 0.2601 |
| 2 | 0.3057 | 0.6500 | 0.6052 | 0.0575 | 0.6030 | 0.4458 | 0.6083 | 0.5172 | 0.0049 | 0.1098 | 0.4684 | 0.3109 | 0.2205 | 0.3140 |
| 3 | 0.5231 | 0.4679 | 0.4561 | 0.4875 | 0.1795 | 0.2725 | 0.4095 | 0.1039 | 0.4295 | 0.4535 | 0.5164 | 0.0416 | 0.2787 | 0.3099 |
| 4 | 0.5826 | 0.1393 | 0.2214 | 0.1400 | 0.4880 | 0.6415 | 0.1767 | 0.0264 | 0.2440 | 0.3034 | 0.5963 | 0.0750 | 0.2426 | 0.2382 |
| 5 | 0.1847 | 0.2846 | 0.3413 | 0.3823 | 0.5506 | 0.5482 | 0.5893 | 0.0576 | 0.5674 | 0.4121 | 0.4530 | 0.1364 | 0.2170 | 0.0458 |
| 6 | 0.0727 | 0.3685 | 0.0711 | 0.0488 | 0.6101 | 0.0475 | 0.6166 | 0.2666 | 0.2234 | 0.4579 | 0.3820 | 0.1698 | 0.0498 | 0.1482 |
| 7 | 0.4066 | 0.5039 | 0.5717 | 0.4513 | 0.5385 | 0.0267 | 0.0481 | 0.4653 | 0.1660 | 0.2271 | 0.6118 | 0.2840 | 0.1963 | 0.0152 |
| 8 | 0.4816 | 0.1362 | 0.2996 | 0.0190 | 0.2630 | 0.1989 | 0.6274 | 0.2983 | 0.5360 | 0.4868 | 0.4263 | 0.3739 | 0.2880 | 0.2401 |
| 9 | 0.3342 | 0.4994 | 0.5851 | 0.0089 | 0.5151 | 0.2762 | 0.4149 | 0.4764 | 0.0338 | 0.3561 | 0.4513 | 0.3003 | 0.0562 | 0.0372 |
| 10 | 0.5831 | 0.0703 | 0.0451 | 0.1888 | 0.4050 | 0.1245 | 0.0603 | 0.4777 | 0.5818 | 0.0234 | 0.1361 | 0.3610 | 0.2667 | 0.1260 |
| 11 | 0.5942 | 0.0891 | 0.2778 | 0.5562 | 0.3067 | 0.0412 | 0.3421 | 0.1389 | 0.2001 | 0.2434 | 0.0691 | 0.2663 | 0.2172 | 0.0178 |
| 12 | 0.4741 | 0.1371 | 0.6155 | 0.2122 | 0.1323 | 0.5615 | | 0.1424 | 0.1574 | 0.6466 | 0.3555 | 0.0378 | 0.2048 | 0.2746 |
| 13 | 0.3999 | 0.5093 | 0.2341 | 0.1250 | 0.4781 | 0.6266 | | 0.5624 | | 0.0299 | 0.3715 | 0.1620 | 0.0188 | 0.2660 |
| 14 | 0.1112 | 0.0044 | 0.3255 | 0.6245 | 0.3761 | 0.1332 | | 0.4012 | | 0.2218 | 0.2430 | | 0.1583 | 0.0896 |
| 15 | 0.4232 | | 0.3483 | 0.2815 | 0.0311 | 0.5983 | | | | | 0.4185 | | 0.3025 | 0.2924 |
| 16 | 0.4306 | | | 0.5393 | 0.1555 | 0.2641 | | | | | | | 0.2320 | |

SMVs of respective operations of part types in Factory 6 continued

| n | t | | | | | | |
|---|---|---|---|---|---|---|---|
| | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 1 | 0.3392 | 0.2157 | 0.2471 | 0.1465 | 0.3145 | 0.0704 | 0.1949 |
| 2 | 0.1542 | 0.3108 | 0.3019 | 0.3329 | 0.2350 | 0.2886 | 0.2224 |
| 3 | 0.0919 | 0.2089 | 0.0787 | 0.2810 | 0.1917 | 0.0661 | 0.2912 |
| 4 | 0.2032 | 0.3427 | 0.2722 | 0.0484 | 0.2842 | 0.1136 | 0.2463 |
| 5 | 0.1637 | 0.1051 | 0.2275 | 0.2288 | 0.0950 | 0.2075 | 0.2200 |
| 6 | 0.2139 | 0.0875 | 0.3428 | 0.2579 | 0.0680 | 0.1001 | 0.1407 |
| 7 | 0.2635 | 0.3201 | 0.1179 | 0.2040 | 0.0581 | 0.3439 | 0.2323 |
| 8 | 0.3093 | 0.1581 | 0.1894 | 0.3474 | 0.3095 | 0.0676 | 0.3532 |
| 9 | 0.1148 | 0.2799 | 0.2595 | 0.2720 | 0.2563 | 0.1792 | 0.0385 |
| 10 | 0.0595 | 0.1596 | 0.1198 | 0.0420 | 0.1492 | 0.0794 | 0.0063 |
| 11 | 0.3454 | 0.0700 | 0.2102 | 0.0571 | 0.1549 | 0.3001 | 0.0989 |
| 12 | 0.3440 | 0.2005 | 0.1214 | 0.2888 | 0.1482 | 0.0761 | 0.2664 |
| 13 | 0.3409 | 0.1785 | 0.0617 | 0.0368 | 0.2962 | 0.0652 | 0.1932 |
| 14 | 0.2376 | 0.1952 | 0.0139 | 0.0941 | | 0.1971 | |
| 15 | 0.3422 | 0.1850 | 0.1146 | 0.1333 | | | |
| 16 | | 0.3021 | 0.1106 | 0.1087 | | | |

Machine setup times for respective settings on each machine type in Factory 6

| i | l | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 1 | 2.17 | 1.07 | 0.85 | 3.13 | 2.73 | 2.10 | 0.72 | 1.98 | 1.87 | |
| 2 | 0.83 | 3.39 | 0.86 | 2.30 | 2.59 | 1.13 | 1.55 | 1.18 | 2.75 | |
| 3 | 2.05 | 3.02 | 0.94 | 2.94 | 0.95 | 2.54 | 2.76 | 1.21 | 2.20 | |
| 4 | 0.86 | 3.05 | 1.91 | 1.77 | 1.17 | 1.47 | 3.28 | 1.07 | 2.50 | |
| 5 | 1.38 | 1.88 | 3.28 | 0.05 | 3.35 | 2.32 | 1.69 | 0.51 | 1.04 | |
| 6 | 1.54 | 1.03 | 1.11 | 1.55 | 1.58 | 2.50 | 1.48 | 0.65 | 3.20 | |
| 7 | 2.45 | 2.00 | 1.85 | 0.42 | 2.69 | 1.28 | 3.12 | 2.06 | 3.27 | |
| 8 | 1.83 | 1.01 | 1.71 | 0.49 | 2.76 | 1.32 | 2.85 | 1.12 | 1.26 | |
| 9 | 0.04 | 2.16 | 1.73 | 1.50 | 1.26 | 2.30 | 0.70 | 0.81 | 1.80 | |
| 10 | 1.99 | 3.41 | 1.36 | 0.49 | 0.70 | 2.34 | 1.61 | 0.62 | 2.83 | |
| 11 | 3.38 | 3.09 | 0.86 | 1.74 | 1.11 | 2.52 | 1.41 | 0.65 | 2.16 | |
| 12 | 2.69 | 2.27 | 2.32 | 0.13 | 3.08 | 3.20 | 1.04 | 3.41 | 2.30 | |
| 13 | 1.99 | 3.41 | 1.03 | 1.11 | 0.94 | 2.94 | 2.76 | 1.21 | 2.20 | |
| 14 | | | | | | | | | | 0.68 |
| 15 | | | | | | | | | | 0.68 |

Random numbers generated based on production downtimes in Factory 6

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 21.572 | 42.435 | 39.542 | 17.204 | 4.222 | 21.486 | 15.604 | 13.208 | 15.485 |
| 12.323 | 4.454 | 34.661 | 13.944 | 26.809 | 20.364 | 33.406 | 23.318 | 34.843 |
| 37.078 | 38.560 | 8.068 | 12.455 | 13.137 | 9.516 | 2.071 | 2.770 | 25.021 |
| 21.914 | 16.754 | 27.198 | 22.336 | 18.690 | 12.863 | 3.133 | 36.474 | 0.941 |
| 15.515 | 8.624 | 24.240 | 8.653 | 12.517 | 36.422 | 40.468 | 30.392 | 12.725 |
| 21.838 | 15.436 | 23.799 | 15.351 | 1.406 | 42.629 | 0.315 | 13.807 | 7.939 |
| 42.417 | 10.851 | 18.674 | 1.745 | 8.816 | 21.120 | 32.921 | 10.205 | 21.046 |
| 41.260 | 28.287 | 33.217 | 3.474 | 41.578 | 27.857 | 34.867 | 41.191 | 41.305 |
| 11.142 | 31.365 | 12.768 | 9.825 | 19.347 | 19.962 | 33.339 | 27.124 | 1.770 |
| 10.783 | 15.785 | 38.225 | 14.803 | 21.788 | 42.113 | 33.219 | 34.651 | 38.024 |
| 24.946 | 9.601 | 1.019 | 9.330 | 9.947 | 10.426 | 40.948 | 21.592 | 37.675 |
| 10.952 | 12.046 | 18.784 | 11.561 | 13.880 | 19.096 | 10.652 | 38.470 | 4.265 |
| 34.661 | 17.457 | 2.080 | 40.778 | 21.122 | 28.449 | 29.075 | 31.059 | 25.970 |
| 31.934 | 2.930 | 42.728 | 25.443 | 0.551 | 17.729 | 42.727 | 23.944 | 29.708 |
| 20.237 | 29.543 | 18.470 | 33.090 | 31.353 | 28.517 | 26.398 | 42.802 | 39.781 |
| 34.806 | 11.394 | 16.666 | 18.709 | 38.872 | 4.595 | 36.839 | 39.819 | 2.617 |
| 13.833 | 28.209 | 7.153 | 3.011 | 2.058 | 37.895 | 30.989 | 15.628 | 4.055 |
| 34.340 | 10.677 | 11.102 | 23.067 | 23.201 | 11.799 | 4.541 | 13.807 | 20.528 |
| 35.546 | 10.650 | 3.419 | 22.467 | 31.338 | 35.795 | 23.258 | 3.724 | 8.665 |

Number of available machines of each type in Factory 6

| $i$ | Total number of available machines |
|---|---|
| 1 | 18 |
| 2 | 22 |
| 3 | 20 |
| 4 | 20 |
| 5 | 27 |
| 6 | 24 |
| 7 | 17 |
| 8 | 17 |
| 9 | 21 |
| 10 | 16 |
| 11 | 22 |
| 12 | 17 |
| 13 | 20 |
| 14 | 26 |
| 15 | 24 |
| 16 | 46 |

Order sequence data of Factory 2 to 6

| Factory | Order sequence |
|---|---|
| 2 | 6, 12, 2, 5, 4, 3 to 7, 11, 9, 8, 10, 1 to 12 |
| 3 | 1,4,6,7,9,2,3,5,8,10,16,22 to 13,15,17,18,19,11,12,14,21,23,20,22 |
| 4 | 1,7,8,9,16,17,18,19,4,2,3,21,24,23,15      to 13,12,11,14,20,22,26,19,5,10,6,21,28,27,25 |
| 5 | 4,3,1,12,15,13,7,8,2,14,17,16 to 11,5,6,12,15,18,9,12,10,21,20,19 |
| 6 | 1,3,4,7,2,9,14,17,20,15,13 to 10,6,8,5,11,18,19,20,21,16 |

Dimensional input data of Factory 2 to 6 (measured in meters)

| Input data | Factory 2 | Factory 3 | Factory 4 | Factory 5 | Factory 6 |
|---|---|---|---|---|---|
| $L_{PF}$ | 65.51 | 88.6 | 95.92 | 68.54 | 70.25 |
| $W_{PF}$ | 48.62 | 53.8 | 58.98 | 40.38 | 58.72 |
| $max\left\{L_{m_{ij}}, L_{oC_k}\right\}$ | 1.22 | 1.2 | 1.26 | 1.18 | 1.25 |
| $max\left\{W_{m_{ij}}, W_{oC_k}\right\}$ | 1.06 | 1.1 | 1.14 | 1.16 | 1 |
| $W_\beta$ | 0.89 | 1.5 | 1 | 1 | 1 |
| $x_D$ | 95.3 | 118.51 | 110.81 | 75.69 | 109.03 |
| $y_D$ | 70.35 | 142.74 | 68.43 | 84.26 | 63.97 |

Other input data used for Factory 2 to 6

| Input data | Factory 2 | Factory 3 | Factory 4 | Factory 5 | Factory 6 |
|---|---|---|---|---|---|
| $U_{m_{i,j}}$(min) | 3.21 | 3.15 | 2.17 | 2.82 | 3.38 |
| $B_t$(pieces) | 8 | 5 | 10 | 10 | 12 |
| $\gamma_t$(\$) | 4.2 | 3.6 | 3.8 | 4.5 | 4.1 |
| $\xi$(min) | 960 | 900 | 960 | 960 | 900 |
| $\psi$ | 4 | 4 | 6 | 5 | 6 |
| $\lambda$ | 12 | 12 | 14 | 10 | 18 |

# APPENDIX H: Output data of system validation

Output data of the system validation for Factory 3 to 6 are given hereafter.

**Part family groups and respective cells of Factory 3 to 6**

| Factory | $b$ | $t$ | $k$ |
|---|---|---|---|
| 3 | 1 | 1,4,6,7,9 | 1,4,6,7,9 |
| | 2 | 13,15,17,18,19 | 13,15,17,18,19 |
| | 3 | 2,3,5,8,10 | 2,3,5,8,10 |
| | 4 | 11,12,14,21,23 | 11,12,14,21,23 |
| | 5 | 16,20 | 16,20 |
| | 6 | 22 | 22 |
| 4 | 1 | 1,7,8,9,11,12,13,14 | 1,7,8,9,11,12,13,14 |
| | 2 | 3,2,6,10 | 3,2,6,10 |
| | 3 | 4,5 | 4,5 |
| | 4 | 19,21 | 19,21 |
| | 5 | 16,17,18 | 16,17,18 |
| | 6 | 20,22,26 | 20,22,26 |
| | 7 | 15,23,24 | 15,23,24 |
| | 8 | 25,27,28 | 25,27,28 |
| 5 | 1 | 1,10 | 1,10 |
| | 2 | 2,3,4,6 | 2,3,4,6 |
| | 3 | 5 | 5 |
| | 4 | 7,8 | 7,8 |
| | 5 | 9,11 | 9,11 |
| | 6 | 14,21 | 14,21 |
| | 7 | 13,18 | 13,18 |
| | 8 | 12,15,16,17,19,20 | 12,15,16,17,19,20 |
| 6 | 1 | 1,3,4,5,6,11 | 1,3,4,5,6,11 |
| | 2 | 2,8,10,12 | 2,8,10,12 |
| | 3 | 7,9 | 7,9 |
| | 4 | 13,15,16,21 | 13,15,16,21 |
| | 5 | 14,17,18,19 | 14,17,18,19 |
| | 6 | 20 | 20 |

**Output data of Factory 3**

Number of machines of each machine type in the dynamic cells in Factory 3

| $i$ | $k$ | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
| 1 | 0 | 0 | 3 | 2 | 0 | 3 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 2 | 1 | 1 | 3 | 0 | 0 | 1 | 2 | 0 | 2 |
| 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 3 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 |
| 3 | 2 | 2 | 3 | 0 | 4 | 1 | 2 | 4 | 1 | 2 | 0 | 1 | 2 | 1 | 0 | 0 | 2 | 3 | 0 | 4 | 1 | 2 | 1 |
| 4 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 1 | 0 | 0 | 1 | 1 | 1 | 2 | 2 | 0 | 1 | 2 | 0 | 0 | 1 | 0 | 1 |
| 5 | 1 | 0 | 0 | 1 | 0 | 4 | 1 | 1 | 1 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 2 | 0 | 0 | 0 | 1 |
| 6 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 3 | 3 | 1 | 0 |
| 7 | 0 | 2 | 0 | 2 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 2 | 1 |
| 8 | 0 | 0 | 2 | 2 | 0 | 1 | 2 | 2 | 0 | 0 | 0 | 0 | 2 | 1 | 2 | 1 | 0 | 2 | 0 | 0 | 1 | 1 | 0 |
| 9 | 2 | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 2 | 0 | 0 | 5 | 3 | 3 | 1 | 3 | 4 | 1 | 0 | 0 | 0 | 0 | 4 |
| 10 | 1 | 2 | 0 | 3 | 0 | 2 | 1 | 0 | 0 | 4 | 2 | 2 | 1 | 0 | 3 | 0 | 2 | 0 | 1 | 0 | 1 | 2 | 1 |
| 11 | 1 | 0 | 3 | 1 | 2 | 0 | 2 | 0 | 4 | 2 | 1 | 2 | 0 | 0 | 2 | 0 | 0 | 1 | 4 | 1 | 0 | 2 | 0 |
| 12 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 2 | 1 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 5 | 1 | 1 |
| 13 | 1 | 3 | 1 | 1 | 2 | 0 | 0 | 1 | 1 | 0 | 4 | 2 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 |
| 14 | 0 | 2 | 1 | 0 | 2 | 1 | 1 | 1 | 2 | 1 | 0 | 2 | 1 | 3 | 1 | 2 | 1 | 2 | 2 | 0 | 1 | 1 | 2 |
| 15 | 4 | 5 | 3 | 4 | 6 | 2 | 5 | 4 | 3 | 6 | 6 | 2 | 4 | 3 | 3 | 4 | 2 | 3 | 4 | 5 | 2 | 2 | 5 |

Operator assignment to operations in dynamic cells in Factory 3

| n | k | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| 1 | 1 | 1 | 1 | 1 | 1,2 | 1 | 1,2 | 1 | 1 | 1,2 | 1,2,3,4 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 2 | 2 | 2 | 1 | 1 | 3,4 | 1,2 | 3 | 1 | 1 | 3,4 | 4 | 2 | 2 | 1 | 2 | 2,3 | 2 | 2 |
| 3 | 3 | 3 | 2 | 2,3 | 5,6 | 3 | 4 | 2 | 2 | 5,6 | 5,6,7 | 2 | 3 | 2 | 3 | 4 | 3 | 3 |
| 4 | 4 | 3 | 2 | 4 | 7,8 | 3 | 5 | 2 | 3 | 7,8 | 8,9,10 | 3 | 4,5 | 3 | 4 | 5 | 4,5 | 4,5 |
| 5 | 4 | 4,5 | 3 | 5,6 | 9,10 | 4 | 5 | 3 | 4 | 9,10 | 11,12,13 | 4 | 6 | 4 | 5 | 6,7 | 5 | 6 |
| 6 | 5 | 6 | 3 | 7,8 | 11,12 | 5,6 | 6 | 3 | 5 | 11,12 | 14,15 | 4 | 7,8 | 5 | 6 | 8 | 6 | 7 |
| 7 | 6 | 7,8 | 4 | 9,10 | 13,14 | 7 | 7 | 4 | 6 | 13,14 | 16 | 5 | 9,10 | 5 | 7 | 9 | 7 | 8 |
| 8 | 7 | 9 | 4 | 11 | 15 | 7 | 8 | 4 | 7 | 14 | 17 | 5 | 11 | 5 | 8 | 10,11 | 8 | 9 |
| 9 | 8 | 10 | 5 | 11 | 16,17 | 8,9 | 8 | 5 | 7 | 15,16 | 17 | 6 | 11 | 6 | 2 | 12 | 8 | 10 |
| 10 | 8 | 10 | 6 | 12,13 | 18,19 | 10 | 9,10 | 5 | 8 | 17 | | 7 | 12 | 7 | 9 | 13 | 9 | 11 |
| 11 | 9 | 11,12 | 6 | 14,15 | | 10 | 11,12 | 5 | 8 | 18 | | 7 | 12 | 8 | 9 | 14 | 10 | 11 |
| 12 | 9 | 13 | 7 | 16 | | 11,12 | 13 | 6 | 8 | 19 | | 8 | | | | | | |
| 13 | 10 | 14,15 | 7 | | | 13 | 14,15 | 6 | 9 | | | 8 | | | | | | |
| 14 | 11 | 16,17 | 8 | | | 14 | 16 | 7 | 9 | | | 9 | | | | | | |
| 15 | 12 | | 8 | | | 15 | | 8 | 10 | | | 10 | | | | | | |
| 16 | 12 | | 9 | | | | | 9 | 11 | | | 11 | | | | | | |
| 17 | 13 | | 10 | | | | | 10 | 11 | | | 12 | | | | | | |
| 18 | 14 | | 11 | | | | | 11 | 12 | | | 13 | | | | | | |
| 19 | | | 11 | | | | | 11 | | | | 14 | | | | | | |
| 20 | | | 11 | | | | | | | | | 15 | | | | | | |

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Operator assignment to operations in dynamic cells in Factory 3 continued

| n | k | | | | |
|---|---|---|---|---|---|
| | 19 | 20 | 21 | 22 | 23 |
| 1 | 1 | 1 | 1 | 1 | 1 |
| 2 | 2,3 | 2 | 2 | 2 | 1 |
| 3 | 4 | 3 | 3 | 2 | 2 |
| 4 | 5 | 3 | 3 | 3,4 | 3 |
| 5 | 6 | 4,5,6 | 4 | 5 | 3 |
| 6 | 6 | 7,8 | 5 | 6 | 4 |
| 7 | 6 | 9 | 5 | 7 | 5 |
| 8 | 7 | 10 | 6,7 | 8 | 6 |
| 9 | 8,9 | 11 | 8 | 9 | 6 |
| 10 | 10 | 12,13,14 | 8 | 10 | 7 |
| 11 | 11,12 | 15 | 9 | 11 | 8 |
| 12 | 13 | | 10 | 12 | 9 |
| 13 | 14,15 | | 11,12 | 13 | 10 |
| 14 | 4 | | 13,14 | 5 | 9 |
| 15 | | | 15 | | 11 |
| 16 | | | 15 | | 12 |
| 17 | | | | | 12 |
| 18 | | | | | 13 |
| 19 | | | | | 14 |
| 20 | | | | | 14 |

Coordinates of dynamic cell locations in Factory 3

| k | x | y | k | x | y |
|---|---|---|---|---|---|
| 1 | 5.95 | 3.50 | 13 | 5.95 | 3.50 |
| 2 | 18.75 | 3.50 | 14 | 18.75 | 20.50 |
| 3 | 18.75 | 12.00 | 15 | 5.95 | 12.00 |
| 4 | 5.95 | 12.00 | 16 | 18.75 | 46.00 |
| 5 | 18.75 | 20.50 | 17 | 5.95 | 20.50 |
| 6 | 5.95 | 20.50 | 18 | 5.95 | 29.00 |
| 7 | 5.95 | 29.00 | 19 | 5.95 | 37.50 |
| 8 | 18.75 | 29.00 | 20 | 18.75 | 46.00 |
| 9 | 5.95 | 37.50 | 21 | 18.75 | 29.00 |
| 10 | 18.75 | 37.50 | 22 | 18.75 | 54.50 |
| 11 | 18.75 | 3.50 | 23 | 18.75 | 37.50 |
| 12 | 18.75 | 12.00 | | | |
| | | | | | |

Machine type at each location in Factory 3

| $g$ | $k$ | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
| 1 | 13 | 7 | 1 | 13 | 11 | 1 | 15 | 8 | 13 | 15 | 13 | 3 | 13 | 2 | 13 | 9 | 1 | 3 | 13 | 11 | 3 | 11 | 14 |
| 2 | 2 | 3 | 14 | 15 | 11 | 8 | 6 | 15 | 6 | 15 | 13 | 4 | 3 | 12 | 2 | 15 | 1 | 3 | 15 | 15 | 1 | 13 | 15 |
| 3 | 5 | 3 | 15 | 4 | 14 | 3 | 4 | 7 | 3 | 10 | 13 | 14 | 9 | 4 | 7 | 15 | 1 | 5 | 2 | 1 | 4 | 7 | 12 |
| 4 | 6 | 13 | 3 | 1 | 14 | 10 | 4 | 13 | 15 | 10 | 13 | 10 | 9 | 3 | 4 | 14 | 5 | 9 | 7 | 7 | 13 | 3 | 10 |
| 5 | 9 | 9 | 1 | 1 | 3 | 4 | 10 | 3 | 9 | 6 | 4 | 12 | 2 | 13 | 4 | 14 | 5 | 14 | 10 | 3 | 7 | 3 | 7 |
| 6 | 10 | 9 | 6 | 8 | 3 | 4 | 8 | 3 | 11 | 6 | 15 | 12 | 8 | 1 | 15 | 9 | 9 | 4 | 15 | 3 | 12 | 8 | 4 |
| 7 | 4 | 4 | 8 | 8 | 9 | 5 | 8 | 9 | 11 | 3 | 15 | 1 | 9 | 15 | 1 | 9 | 9 | 4 | 5 | 3 | 6 | 12 | 13 |
| 8 | 6 | 14 | 13 | 9 | 9 | 5 | 3 | 8 | 7 | 3 | 15 | 13 | 4 | 14 | 10 | 8 | 3 | 11 | 5 | 6 | 6 | 11 | 1 |
| 9 | 11 | 14 | 3 | 7 | 13 | 9 | 15 | 14 | 5 | 11 | 5 | 9 | 6 | 9 | 10 | 1 | 3 | 8 | 12 | 6 | 6 | 7 | 9 |
| 10 | 12 | 13 | 9 | 7 | 13 | 5 | 15 | 15 | 12 | 11 | 5 | 10 | 3 | 4 | 11 | 7 | 7 | 8 | 11 | 6 | 1 | 14 | 3 |
| 11 | 12 | 13 | 1 | 5 | 15 | 5 | 5 | 3 | 12 | 10 | 5 | 9 | 15 | 6 | 11 | 7 | 4 | 2 | 11 | 3 | 14 | 10 | 9 |
| 12 | 15 | 15 | 11 | 10 | 15 | 1 | 9 | 12 | 9 | 10 | 2 | 9 | 15 | 1 | 8 | 2 | 9 | 15 | 11 | 2 | 10 | 10 | 9 |
| 13 | 3 | 10 | 11 | 10 | 3 | 1 | 3 | 4 | 11 | 15 | 2 | 11 | 10 | 9 | 8 | 6 | 9 | 7 | 11 | 15 | 8 | 6 | 15 |
| 14 | 2 | 10 | 4 | 10 | 3 | 9 | 11 | 5 | 11 | 15 | 2 | 14 | 12 | 8 | 9 | 13 | 10 | 3 | 6 | 15 | 12 | 15 | 9 |
| 15 | 3 | 7 | 3 | 11 | 4 | 10 | 11 | 2 | 12 | 14 | 10 | 9 | 8 | 12 | 10 | 15 | 10 | 14 | 14 | 15 | 12 | 15 | 15 |
| 16 | 9 | 15 | 8 | 15 | 15 | 14 | 14 | 3 | 14 | 1 | 10 | 11 | 14 | 14 | 14 | 15 | 14 | 15 | 14 | 15 | 12 | | 14 |
| 17 | 15 | 15 | 11 | 15 | 15 | 15 | 15 | 6 | 15 | 1 | 11 | 9 | 15 | 14 | 15 | | 15 | 15 | 15 | | 12 | | 5 |
| 18 | 15 | 15 | 12 | 15 | 15 | 15 | 15 | 15 | 15 | 7 | 15 | 13 | 15 | 9 | 15 | | 15 | | 15 | | 15 | | 1 |
| 19 | | 15 | 15 | | 15 | | | 15 | | 15 | 15 | 15 | | 15 | | | | | | | 15 | | 15 |
| 20 | | | 15 | | | | | | | 15 | 15 | 15 | | 15 | | | | | | | | | 15 |

x-coordinate values for machine locations in dynamic cells in Factory 3

| g | k | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 1 | 0.20 | 14.00 | 14.00 | 0.20 | 14.00 | 0.20 | 0.20 | 14.00 | 0.20 | 14.00 | 14.00 | 14.00 | 0.20 | 14.00 | 0.20 | 14.00 |
| 2 | 1.40 | 15.20 | 15.20 | 1.40 | 15.20 | 1.40 | 1.40 | 15.20 | 1.40 | 15.20 | 15.20 | 15.20 | 1.40 | 15.20 | 1.40 | 15.20 |
| 3 | 2.60 | 16.40 | 16.40 | 2.60 | 16.40 | 2.60 | 2.60 | 16.40 | 2.60 | 16.40 | 16.40 | 16.40 | 2.60 | 16.40 | 2.60 | 16.40 |
| 4 | 3.80 | 17.60 | 17.60 | 3.80 | 17.60 | 3.80 | 3.80 | 17.60 | 3.80 | 17.60 | 17.60 | 17.60 | 3.80 | 17.60 | 3.80 | 17.60 |
| 5 | 5.00 | 18.80 | 18.80 | 5.00 | 18.80 | 5.00 | 5.00 | 18.80 | 5.00 | 18.80 | 18.80 | 18.80 | 5.00 | 18.80 | 5.00 | 18.80 |
| 6 | 6.20 | 20.00 | 20.00 | 6.20 | 20.00 | 6.20 | 6.20 | 20.00 | 6.20 | 20.00 | 20.00 | 20.00 | 6.20 | 20.00 | 6.20 | 20.00 |
| 7 | 7.40 | 21.20 | 21.20 | 7.40 | 21.20 | 7.40 | 7.40 | 21.20 | 7.40 | 21.20 | 21.20 | 21.20 | 7.40 | 21.20 | 7.40 | 21.20 |
| 8 | 11.35 | 22.40 | 22.40 | 11.35 | 22.40 | 11.35 | 11.35 | 22.40 | 11.35 | 22.40 | 22.40 | 22.40 | 11.35 | 22.40 | 11.35 | 11.00 |
| 9 | 11.35 | 11.35 | 11.35 | 11.35 | 11.35 | 11.35 | 11.35 | 11.35 | 11.35 | 11.35 | 11.35 | 11.35 | 11.35 | 11.35 | 11.35 | 11.00 |
| 10 | 11.35 | 11.35 | 11.35 | 11.35 | 11.35 | 11.35 | 11.35 | 11.35 | 11.35 | 11.35 | 11.35 | 11.35 | 11.35 | 11.35 | 11.35 | 21.20 |
| 11 | 11.35 | 11.35 | 11.35 | 11.35 | 11.35 | 11.35 | 11.35 | 11.35 | 11.35 | 11.35 | 11.35 | 11.35 | 11.35 | 11.35 | 11.35 | 20.00 |
| 12 | 7.40 | 11.35 | 11.35 | 7.40 | 11.35 | 7.40 | 7.40 | 11.35 | 7.40 | 11.35 | 11.35 | 11.35 | 7.40 | 11.35 | 7.40 | 18.80 |
| 13 | 6.20 | 22.40 | 22.40 | 6.20 | 22.40 | 6.20 | 6.20 | 22.40 | 6.20 | 22.40 | 22.40 | 22.40 | 6.20 | 22.40 | 6.20 | 17.60 |
| 14 | 5.00 | 21.20 | 21.20 | 5.00 | 21.20 | 5.00 | 5.00 | 21.20 | 5.00 | 21.20 | 21.20 | 21.20 | 5.00 | 21.20 | 5.00 | 16.40 |
| 15 | 3.80 | 20.00 | 20.00 | 3.80 | 20.00 | 3.80 | 3.80 | 20.00 | 3.80 | 20.00 | 20.00 | 20.00 | 3.80 | 20.00 | 3.80 | 15.20 |
| 16 | 2.60 | 18.80 | 18.80 | 2.60 | 18.80 | 2.60 | 2.60 | 18.80 | 2.60 | 18.80 | 18.80 | 18.80 | 2.60 | 18.80 | 2.60 | 14.00 |
| 17 | 1.40 | 17.60 | 17.60 | 1.40 | 17.60 | 1.40 | 1.40 | 17.60 | 1.40 | 17.60 | 17.60 | 17.60 | 1.40 | 17.60 | 1.40 | |
| 18 | 0.20 | 16.40 | 16.40 | 0.20 | 16.40 | 0.20 | 0.20 | 16.40 | 0.20 | 16.40 | 16.40 | 16.40 | 0.20 | 16.40 | 0.20 | |
| 19 | | 15.20 | 15.20 | | 15.20 | | | 15.20 | | 15.20 | 15.20 | 15.20 | | 15.20 | | |
| 20 | | | 14.00 | | | | | | | 14.00 | 14.00 | 14.00 | | 14.00 | | |

x-coordinate values for machine locations in dynamic cells in Factory 3 continued

| $g$ | $k$ | | | | | | |
|---|---|---|---|---|---|---|---|
| | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
| 1 | 0.20 | 0.20 | 0.20 | 14.00 | 14.00 | 14.00 | 14.00 |
| 2 | 1.40 | 1.40 | 1.40 | 15.20 | 15.20 | 15.20 | 15.20 |
| 3 | 2.60 | 2.60 | 2.60 | 16.40 | 16.40 | 16.40 | 16.40 |
| 4 | 3.80 | 3.80 | 3.80 | 17.60 | 17.60 | 17.60 | 17.60 |
| 5 | 5.00 | 5.00 | 5.00 | 18.80 | 18.80 | 18.80 | 18.80 |
| 6 | 6.20 | 6.20 | 6.20 | 20.00 | 20.00 | 20.00 | 20.00 |
| 7 | 7.40 | 7.40 | 7.40 | 21.20 | 21.20 | 21.20 | 21.20 |
| 8 | 11.35 | 11.35 | 11.35 | 11.00 | 22.40 | 11.00 | 22.40 |
| 9 | 11.35 | 11.35 | 11.35 | 11.00 | 11.35 | 11.00 | 11.35 |
| 10 | 11.35 | 11.35 | 11.35 | 21.20 | 11.35 | 21.20 | 11.35 |
| 11 | 11.35 | 11.35 | 11.35 | 20.00 | 11.35 | 20.00 | 11.35 |
| 12 | 7.40 | 7.40 | 7.40 | 18.80 | 11.35 | 18.80 | 11.35 |
| 13 | 6.20 | 6.20 | 6.20 | 17.60 | 22.40 | 17.60 | 22.40 |
| 14 | 5.00 | 5.00 | 5.00 | 16.40 | 21.20 | 16.40 | 21.20 |
| 15 | 3.80 | 3.80 | 3.80 | 15.20 | 20.00 | 15.20 | 20.00 |
| 16 | 2.60 | 2.60 | 2.60 | 14.00 | 18.80 | | 18.80 |
| 17 | 1.40 | 1.40 | 1.40 | | 17.60 | | 17.60 |
| 18 | 0.20 | 0.20 | 0.20 | | 16.40 | | 16.40 |
| 19 | | | | | 15.20 | | 15.20 |
| 20 | | | | | | | 14.00 |

y-coordinate values for machine locations in dynamic cells in Factory 3

| g | k | | | | | | | | | | | | | | | |
|---|------|------|-------|-------|-------|-------|-------|-------|-------|-------|------|-------|------|-------|-------|-------|
|   | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 1 | 0.55 | 0.55 | 9.05 | 9.05 | 17.55 | 17.55 | 26.05 | 26.05 | 34.55 | 34.55 | 0.55 | 9.05 | 0.55 | 17.55 | 9.05 | 43.05 |
| 2 | 0.55 | 0.55 | 9.05 | 9.05 | 17.55 | 17.55 | 26.05 | 26.05 | 34.55 | 34.55 | 0.55 | 9.05 | 0.55 | 17.55 | 9.05 | 43.05 |
| 3 | 0.55 | 0.55 | 9.05 | 9.05 | 17.55 | 17.55 | 26.05 | 26.05 | 34.55 | 34.55 | 0.55 | 9.05 | 0.55 | 17.55 | 9.05 | 43.05 |
| 4 | 0.55 | 0.55 | 9.05 | 9.05 | 17.55 | 17.55 | 26.05 | 26.05 | 34.55 | 34.55 | 0.55 | 9.05 | 0.55 | 17.55 | 9.05 | 43.05 |
| 5 | 0.55 | 0.55 | 9.05 | 9.05 | 17.55 | 17.55 | 26.05 | 26.05 | 34.55 | 34.55 | 0.55 | 9.05 | 0.55 | 17.55 | 9.05 | 43.05 |
| 6 | 0.55 | 0.55 | 9.05 | 9.05 | 17.55 | 17.55 | 26.05 | 26.05 | 34.55 | 34.55 | 0.55 | 9.05 | 0.55 | 17.55 | 9.05 | 43.05 |
| 7 | 0.55 | 0.55 | 9.05 | 9.05 | 17.55 | 17.55 | 26.05 | 26.05 | 34.55 | 34.55 | 0.55 | 9.05 | 0.55 | 17.55 | 9.05 | 43.05 |
| 8 | 1.70 | 0.55 | 9.05 | 10.20 | 17.55 | 18.70 | 27.20 | 26.05 | 35.70 | 34.55 | 0.55 | 9.05 | 1.70 | 17.55 | 10.20 | 44.20 |
| 9 | 2.90 | 1.70 | 10.20 | 11.40 | 18.70 | 19.90 | 28.40 | 27.20 | 36.90 | 35.70 | 1.70 | 10.20 | 2.90 | 18.70 | 11.40 | 45.40 |
| 10 | 4.10 | 2.90 | 11.40 | 12.60 | 19.90 | 21.10 | 29.60 | 28.40 | 38.10 | 36.90 | 2.90 | 11.40 | 4.10 | 19.90 | 12.60 | 46.55 |
| 11 | 5.30 | 4.10 | 12.60 | 13.80 | 21.10 | 22.30 | 30.80 | 29.60 | 39.30 | 38.10 | 4.10 | 12.60 | 5.30 | 21.10 | 13.80 | 46.55 |
| 12 | 6.45 | 5.30 | 13.80 | 14.95 | 22.30 | 23.45 | 31.95 | 30.80 | 40.45 | 39.30 | 5.30 | 13.80 | 6.45 | 22.30 | 14.95 | 46.55 |
| 13 | 6.45 | 6.45 | 14.95 | 14.95 | 23.45 | 23.45 | 31.95 | 31.95 | 40.45 | 40.45 | 6.45 | 14.95 | 6.45 | 23.45 | 14.95 | 46.55 |
| 14 | 6.45 | 6.45 | 14.95 | 14.95 | 23.45 | 23.45 | 31.95 | 31.95 | 40.45 | 40.45 | 6.45 | 14.95 | 6.45 | 23.45 | 14.95 | 46.55 |
| 15 | 6.45 | 6.45 | 14.95 | 14.95 | 23.45 | 23.45 | 31.95 | 31.95 | 40.45 | 40.45 | 6.45 | 14.95 | 6.45 | 23.45 | 14.95 | 46.55 |
| 16 | 6.45 | 6.45 | 14.95 | 14.95 | 23.45 | 23.45 | 31.95 | 31.95 | 40.45 | 40.45 | 6.45 | 14.95 | 6.45 | 23.45 | 14.95 | 46.55 |
| 17 | 6.45 | 6.45 | 14.95 | 14.95 | 23.45 | 23.45 | 31.95 | 31.95 | 40.45 | 40.45 | 6.45 | 14.95 | 6.45 | 23.45 | 14.95 | |
| 18 | 6.45 | 6.45 | 14.95 | 14.95 | 23.45 | 23.45 | 31.95 | 31.95 | 40.45 | 40.45 | 6.45 | 14.95 | 6.45 | 23.45 | 14.95 | |
| 19 | | 6.45 | 14.95 | | 23.45 | | | 31.95 | | 40.45 | 6.45 | 14.95 | | 23.45 | | |
| 20 | | | 14.95 | | | | | | | 40.45 | 6.45 | 14.95 | | 23.45 | | |

y-coordinate values for machine locations in dynamic cells in Factory 3 continued

| g | k | | | | | | |
|---|---|---|---|---|---|---|---|
| | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
| 1 | 17.55 | 26.05 | 34.55 | 43.05 | 26.05 | 49.15 | 34.55 |
| 2 | 17.55 | 26.05 | 34.55 | 43.05 | 26.05 | 49.15 | 34.55 |
| 3 | 17.55 | 26.05 | 34.55 | 43.05 | 26.05 | 49.15 | 34.55 |
| 4 | 17.55 | 26.05 | 34.55 | 43.05 | 26.05 | 49.15 | 34.55 |
| 5 | 17.55 | 26.05 | 34.55 | 43.05 | 26.05 | 49.15 | 34.55 |
| 6 | 17.55 | 26.05 | 34.55 | 43.05 | 26.05 | 49.15 | 34.55 |
| 7 | 17.55 | 26.05 | 34.55 | 43.05 | 26.05 | 49.15 | 34.55 |
| 8 | 18.70 | 27.20 | 35.70 | 44.20 | 26.05 | 50.30 | 34.55 |
| 9 | 19.90 | 28.40 | 36.90 | 45.40 | 27.20 | 51.50 | 35.70 |
| 10 | 21.10 | 29.60 | 38.10 | 46.55 | 28.40 | 52.65 | 36.90 |
| 11 | 22.30 | 30.80 | 39.30 | 46.55 | 29.60 | 52.65 | 38.10 |
| 12 | 23.45 | 31.95 | 40.45 | 46.55 | 30.80 | 52.65 | 39.30 |
| 13 | 23.45 | 31.95 | 40.45 | 46.55 | 31.95 | 52.65 | 40.45 |
| 14 | 23.45 | 31.95 | 40.45 | 46.55 | 31.95 | 52.65 | 40.45 |
| 15 | 23.45 | 31.95 | 40.45 | 46.55 | 31.95 | 52.65 | 40.45 |
| 16 | 23.45 | 31.95 | 40.45 | 46.55 | 31.95 | | 40.45 |
| 17 | 23.45 | 31.95 | 40.45 | | 31.95 | | 40.45 |
| 18 | 23.45 | | 40.45 | | 31.95 | | 40.45 |
| 19 | | | | | 31.95 | | 40.45 |
| 20 | | | | | | | 40.45 |

**Output data of Factory 4**

Number of machines of each machine type in the dynamic cells in Factory 4

| $i$ | $k$ |
|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 1 | 0 | 0 | 0 | 1 | 0 | 0 | 3 | 1 | 2 | 0 | 1 | 2 | 1 | 2 | 0 | 1 | 0 | 5 | 1 | 0 | 0 | 3 | 2 | 1 | 1 | 0 | 2 | 0 |
| 2 | 1 | 3 | 3 | 0 | 5 | 2 | 0 | 0 | 1 | 3 | 1 | 0 | 1 | 2 | 1 | 0 | 2 | 1 | 1 | 0 | 3 | 0 | 2 | 1 | 2 | 1 | 0 | 2 |
| 3 | 1 | 0 | 4 | 1 | 1 | 2 | 2 | 0 | 1 | 0 | 3 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 2 | 0 | 2 | 1 | 1 | 0 | 2 | 1 | 1 |
| 4 | 1 | 0 | 1 | 3 | 3 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 |
| 5 | 4 | 1 | 0 | 3 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 4 | 1 | 0 | 2 | 2 | 0 |
| 6 | 2 | 4 | 1 | 0 | 0 | 0 | 2 | 1 | 2 | 0 | 1 | 2 | 1 | 0 | 0 | 4 | 1 | 0 | 0 | 0 | 2 | 1 | 0 | 1 | 2 | 3 | 0 | 0 |
| 7 | 0 | 3 | 1 | 1 | 0 | 1 | 0 | 2 | 0 | 3 | 2 | 0 | 0 | 1 | 2 | 1 | 2 | 0 | 1 | 3 | 2 | 2 | 0 | 0 | 1 | 0 | 0 | 1 |
| 8 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 3 | 1 | 0 | 1 | 3 | 3 | 2 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 2 | 1 | 0 | 4 | 1 |
| 9 | 0 | 2 | 1 | 0 | 2 | 1 | 0 | 2 | 0 | 3 | 0 | 2 | 0 | 1 | 0 | 0 | 2 | 1 | 2 | 1 | 0 | 3 | 0 | 1 | 1 | 1 | 1 | 1 |
| 10 | 0 | 0 | 1 | 2 | 0 | 4 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 0 | 1 | 0 | 3 | 1 | 1 | 0 | 1 | 2 | 2 | 0 | 3 |
| 11 | 1 | 1 | 2 | 1 | 2 | 2 | 1 | 2 | 0 | 1 | 1 | 2 | 0 | 0 | 2 | 1 | 3 | 1 | 3 | 1 | 0 | 1 | 1 | 2 | 1 | 0 | 1 | 0 |
| 12 | 2 | 4 | 2 | 6 | 4 | 4 | 5 | 3 | 5 | 2 | 4 | 2 | 5 | 4 | 4 | 3 | 3 | 2 | 2 | 4 | 5 | 2 | 2 | 3 | 2 | 3 | 3 | 4 |

Operator assignment to operations in dynamic cells in Factory 4

| n | k | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| 1 | 1 | 1 | 1,2 | 1,2 | 1 | 1 | 1 | 1 | 1,2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1,2 | 1 | 1 | 1 |
| 2 | 2,3 | 1 | 2,3 | 3 | 1,2 | 2 | 2,3 | 2 | 3 | 2 | 2,3 | 1 | 2 | 2,3 | 2 | 1 | 3 | 2 | 1 | 2 |
| 3 | 4 | 2 | 4 | 3 | 3 | 3 | 4,5 | 3 | 4,5 | 2 | 4 | 2 | 2 | 4 | 3 | 2 | 4 | 3 | 2 | 2 |
| 4 | 5 | 3 | 5 | 4 | 4,5 | 4 | 5 | 4 | 6,7 | 3,4 | 5,6 | 3 | 3,4 | 5,6 | 4 | 3 | 4 | 4,5 | 3 | 3 |
| 5 | 6 | 3 | 6 | 5 | 6,7 | 5 | 5 | 4 | 8 | 4 | 7 | 4 | 5 | 7 | 5,6 | 4 | 5,6 | 6 | 4 | 4 |
| 6 | 7 | 4,5 | 7,8 | 5,6 | 8 | 5 | 6,7 | 5,6 | 9 | 5,6 | 8 | 5 | 6,7 | 8 | 7 | 5 | 7,8 | 7 | 5 | 5 |
| 7 | 8 | 6 | 8,9 | 7 | 9 | 6 | 7 | 6 | 9 | 7,8,9 | 9 | 6 | 8 | 9 | 8 | 6 | 9 | 8,9 | 6 | 6 |
| 8 | 8 | 7 | 10 | 7,8 | 10 | 7 | 8,9 | 7,8 | 10 | 9 | 10 | 7 | 8 | 9,10 | 9 | 7 | 9 | 10 | 7 | 7 |
| 9 | 9 | 8 | 4 | 9 | 10 | 8 | 10,11 | 9 | 11 | 10 | 11 | 7,8 | 9,10 | 10 | 10 | 8 | 10 | 11 | 8 | 8 |
| 10 | 6 | 8,9 | 11 | 9 | 10 | 8 | | 10 | 12,13 | 11 | 12 | 9 | 11,12 | 11 | 4 | 9 | 11 | 11 | 9 | 9 |
| 11 | 10 | 10 | 12 | 10,11 | 11,12 | 9 | | 11 | | | 12 | 10 | | 12 | 11 | 10 | 11 | 11 | 9 | 9 |
| 12 | 10 | 11 | | 12,13 | | 9 | | 12 | | | 13 | 11 | | | 12 | 10 | | 12 | | 10 |
| 13 | 11 | 11 | | 13 | | 10 | | | | | | 12 | | | 12 | 11 | | 12 | | 11 |
| 14 | | 12,13 | | | | 11 | | | | | | | | | | 12 | | | | 12 |
| 15 | | 13 | | | | 12 | | | | | | | | | | 13 | | | | 13 |

Operator assignment to operations in dynamic cells in Factory 4 continued

| n | k | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 1 | 1 | 1 | 1 | 1 | 1,2 | 1 | 1 | 1 |
| 2 | 2 | 1 | 2,3 | 1 | 3 | 2 | 2 | 1 |
| 3 | 3 | 2,3 | 4 | 1 | 3 | 3 | 2 | 1 |
| 4 | 3 | 4,5 | 4 | 2 | 4 | 4,5 | 3,4 | 2 |
| 5 | 4,5 | 6 | 5,6 | 3 | 4 | 6 | 5 | 3 |
| 6 | 6 | 7,8 | 6 | 4 | 5 | 7 | 5 | 4 |
| 7 | 7 | 9 | 7 | 5 | 6 | 7 | 6 | 5,6 |
| 8 | 8 | 9 | 8,9 | 6 | 7 | 7 | 7 | 2 |
| 9 | 8 | 10 | 10 | 7 | 8 | 8 | 8,9 | 7,8 |
| 10 | | 11 | 11 | 8 | 9 | 9,10 | 10 | 9,10 |
| 11 | | 11 | | | 10 | 11 | | 11 |
| 12 | | 12 | | | 11 | 12 | | |
| 13 | | | | | | 13 | | |
| 14 | | | | | | | | |
| 15 | | | | | | | | |

Coordinates of dynamic cell locations in Factory 4

| k | x | y | k | x | y |
|---|---|---|---|---|---|
| 1 | 4.62 | 2.4 | 15 | 40.94 | 2.4 |
| 2 | 15.43 | 9.34 | 16 | 29.98 | 3.03 |
| 3 | 15.43 | 2.4 | 17 | 29.98 | 10.09 |
| 4 | 16 | 16.85 | 18 | 29.98 | 17.15 |
| 5 | 16 | 14.57 | 19 | 29.35 | 23.58 |
| 6 | 15.43 | 2.4 | 20 | 29.98 | 3.03 |
| 7 | 4.62 | 8.2 | 21 | 40.94 | 19.8 |
| 8 | 4.62 | 14 | 22 | 29.98 | 10.09 |
| 9 | 4.62 | 19.8 | 23 | 40.94 | 8.2 |
| 10 | 15.43 | 8.2 | 24 | 40.94 | 14 |
| 11 | 4.62 | 8.2 | 25 | 40.94 | 2.4 |
| 12 | 4.62 | 14 | 26 | 29.98 | 17.15 |
| 13 | 4.62 | 19.8 | 27 | 40.94 | 8.2 |
| 14 | 4.62 | 8.2 | 28 | 40.94 | 14 |

Machine type at each location in Factory 4

| g | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 |
|---|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| | | | | | | | | | | | | | | | | | | $k$ | | | | | | | | | | |
| 1 | 11 | 12 | 3 | 10 | 2 | 3 | 12 | 1 | 8 | 2 | 6 | 8 | 1 | 7 | 8 | 4 | 7 | 11 | 9 | 9 | 6 | 11 | 4 | 11 | 6 | 6 | 11 | 3 |
| 2 | 5 | 7 | 3 | 10 | 2 | 10 | 6 | 12 | 8 | 11 | 7 | 11 | 8 | 1 | 7 | 6 | 7 | 3 | 2 | 12 | 12 | 1 | 2 | 6 | 6 | 5 | 1 | 9 |
| 3 | 5 | 5 | 3 | 4 | 2 | 10 | 6 | 10 | 2 | | 7 | 6 | 4 | 1 | 5 | 10 | 9 | 1 | 8 | 10 | 7 | 7 | 2 | 12 | 2 | 4 | 8 | 12 |
| 4 | 4 | 2 | 3 | 3 | 2 | 3 | 1 | 9 | 6 | 7 | 11 | 1 | 10 | 8 | 2 | 6 | 9 | 1 | 7 | 10 | 6 | 7 | 8 | 3 | 8 | 10 | 5 | 7 |
| 5 | 5 | 6 | 4 | 1 | 4 | 12 | 1 | 6 | 6 | 7 | 3 | 9 | 10 | 2 | 12 | 1 | 8 | 1 | 9 | 3 | 2 | 9 | 1 | 9 | 10 | 10 | 5 | 4 |
| 6 | 6 | 6 | 6 | 11 | 4 | 11 | 1 | 11 | 1 | 8 | 3 | 9 | 2 | 2 | 12 | 6 | 2 | 5 | 11 | 7 | 2 | 9 | 5 | 5 | 1 | 2 | 12 | 8 |
| 7 | 8 | 6 | 10 | 4 | 2 | 7 | 8 | 11 | 1 | 2 | 1 | 11 | 8 | 5 | 11 | 5 | 2 | 2 | 5 | 11 | 10 | 1 | 5 | 11 | 2 | 9 | 8 | 10 |
| 8 | 2 | 9 | 11 | 4 | 9 | 12 | 3 | 8 | 12 | 2 | 12 | 5 | 8 | 9 | 8 | 4 | 11 | 1 | 11 | 8 | 12 | 3 | 11 | 1 | 9 | 12 | 3 | 10 |
| 9 | 5 | 7 | 11 | 7 | 9 | 9 | 3 | 7 | 3 | 9 | 5 | 6 | 6 | 12 | 4 | 12 | 11 | 1 | 1 | 10 | 12 | 3 | 1 | 8 | 10 | 5 | 1 | 10 |
| 10 | 3 | 7 | 2 | 12 | 11 | 10 | 11 | 7 | 12 | 9 | 3 | 5 | 12 | 8 | 7 | 7 | 6 | 8 | 11 | 7 | 2 | 6 | 5 | 8 | 11 | 3 | 8 | 2 |
| 11 | 8 | 2 | 2 | 12 | 11 | 10 | 12 | 4 | 8 | 9 | 2 | 3 | 12 | 8 | 3 | 11 | 11 | 4 | 12 | 7 | 7 | 10 | 5 | 2 | 7 | 6 | 8 | 2 |
| 12 | 6 | 2 | 2 | 5 | 3 | 11 | 12 | 9 | 12 | 5 | 12 | 1 | 12 | 12 | 11 | 10 | 12 | 10 | 12 | 3 | 12 | 9 | 3 | 10 | 12 | 6 | 9 | 12 |
| 13 | 12 | 6 | 9 | 12 | 4 | 2 | 12 | 12 | 12 | 7 | 12 | 12 | 12 | 12 | 12 | 6 | 3 | 9 | | 12 | 12 | 1 | 12 | 12 | 12 | 3 | 12 | 12 |
| 14 | 12 | 11 | 7 | 5 | 12 | 2 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | | 12 | | 12 | 12 | 12 | | 12 | 12 | 12 |
| 15 | | 9 | 12 | 5 | 5 | 12 | | | | 12 | | | | | | 12 | 12 | 12 | | 12 | | 12 | | | | | 12 | |
| 16 | | 12 | 12 | 12 | 12 | 12 | | | | | | | | | | | | | | | | | | | | | | |
| 17 | | 12 | | 12 | 12 | | | | | | | | | | | | | | | | | | | | | | | |
| 18 | | 12 | | 12 | 12 | | | | | | | | | | | | | | | | | | | | | | | |

x-coordinate values for machine locations in dynamic cells in Factory 4

| g | k | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 1 | 0.57 | 10.18 | 10.18 | 10.18 | 10.18 | 10.18 | 0.57 | 0.57 | 0.57 | 10.18 | 0.57 | 0.57 | 0.57 | 0.57 |
| 2 | 1.71 | 11.32 | 11.32 | 11.32 | 11.32 | 11.32 | 1.71 | 1.71 | 1.71 | 11.32 | 1.71 | 1.71 | 1.71 | 1.71 |
| 3 | 2.85 | 12.46 | 12.46 | 12.46 | 12.46 | 12.46 | 2.85 | 2.85 | 2.85 | 12.46 | 2.85 | 2.85 | 2.85 | 2.85 |
| 4 | 3.99 | 13.6 | 13.6 | 13.6 | 13.6 | 13.6 | 3.99 | 3.99 | 3.99 | 13.6 | 3.99 | 3.99 | 3.99 | 3.99 |
| 5 | 5.13 | 14.74 | 14.74 | 14.74 | 14.74 | 14.74 | 5.13 | 5.13 | 5.13 | 14.74 | 5.13 | 5.13 | 5.13 | 5.13 |
| 6 | 6.27 | 15.88 | 15.88 | 15.88 | 15.88 | 15.88 | 6.27 | 6.27 | 6.27 | 15.88 | 6.27 | 6.27 | 6.27 | 6.27 |
| 7 | 7.47 | 17.02 | 17.02 | 17.02 | 17.02 | 17.02 | 7.47 | 7.47 | 7.47 | 17.02 | 7.47 | 7.47 | 7.47 | 7.47 |
| 8 | 7.47 | 19.36 | 19.36 | 18.16 | 18.16 | 19.36 | 7.47 | 7.47 | 7.47 | 19.36 | 7.47 | 7.47 | 7.47 | 7.47 |
| 9 | 6.27 | 19.36 | 19.36 | 10.89 | 10.89 | 19.36 | 6.27 | 6.27 | 6.27 | 19.36 | 6.27 | 6.27 | 6.27 | 6.27 |
| 10 | 5.13 | 19.36 | 17.02 | 10.89 | 10.89 | 17.02 | 5.13 | 5.13 | 5.13 | 17.02 | 5.13 | 5.13 | 5.13 | 5.13 |
| 11 | 3.99 | 19.36 | 15.88 | 10.89 | 10.89 | 15.88 | 3.99 | 3.99 | 3.99 | 15.88 | 3.99 | 3.99 | 3.99 | 3.99 |
| 12 | 2.85 | 17.02 | 14.74 | 18.16 | 18.16 | 14.74 | 2.85 | 2.85 | 2.85 | 14.74 | 2.85 | 2.85 | 2.85 | 2.85 |
| 13 | 1.71 | 15.88 | 13.6 | 17.02 | 17.02 | 13.6 | 1.71 | 1.71 | 1.71 | 13.6 | 1.71 | 1.71 | 1.71 | 1.71 |
| 14 | 0.57 | 14.74 | 12.46 | 15.88 | 15.88 | 12.46 | 0.57 | 0.57 | 0.57 | 12.46 | 0.57 | 0.57 | 0.57 | 0.57 |
| 15 | | 13.6 | 11.32 | 14.74 | 14.74 | 11.32 | | | | 11.32 | | | | |
| 16 | | 12.46 | 10.18 | 13.6 | 13.6 | 10.18 | | | | 10.18 | | | | |
| 17 | | 11.32 | | 12.46 | 12.46 | | | | | | | | | |
| 18 | | 10.18 | | 11.32 | 11.32 | | | | | | | | | |

x-coordinate values for machine locations in dynamic cells in Factory 4 continued

| g | k | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 1 | 36.59 | 25.63 | 25.63 | 25.63 | 25.63 | 25.63 | 36.59 | 25.63 | 36.59 | 36.59 | 36.59 | 25.63 | 36.59 | 36.59 |
| 2 | 37.85 | 26.89 | 26.89 | 26.89 | 26.89 | 26.89 | 37.85 | 26.89 | 37.85 | 37.85 | 37.85 | 26.89 | 37.85 | 37.85 |
| 3 | 39.11 | 28.15 | 28.15 | 28.15 | 28.15 | 28.15 | 39.11 | 28.15 | 39.11 | 39.11 | 39.11 | 28.15 | 39.11 | 39.11 |
| 4 | 40.37 | 29.41 | 29.41 | 29.41 | 29.41 | 29.41 | 40.37 | 29.41 | 40.37 | 40.37 | 40.37 | 29.41 | 40.37 | 40.37 |
| 5 | 41.63 | 30.67 | 30.67 | 30.67 | 30.67 | 30.67 | 41.63 | 30.67 | 41.63 | 41.63 | 41.63 | 30.67 | 41.63 | 41.63 |
| 6 | 42.89 | 31.93 | 31.93 | 31.93 | 33.13 | 31.93 | 42.89 | 31.93 | 42.89 | 42.89 | 42.89 | 31.93 | 42.89 | 42.89 |
| 7 | 45.35 | 8.13 | 8.13 | 8.13 | 33.13 | 8.13 | 45.35 | 8.13 | 45.35 | 45.35 | 45.35 | 8.13 | 45.35 | 45.35 |
| 8 | 45.35 | 8.13 | 8.13 | 8.13 | 30.67 | 8.13 | 45.35 | 8.13 | 45.35 | 45.35 | 45.35 | 8.13 | 45.35 | 45.35 |
| 9 | 42.89 | 8.13 | 8.13 | 8.13 | 29.41 | 8.13 | 42.89 | 8.13 | 42.89 | 42.89 | 42.89 | 8.13 | 42.89 | 42.89 |
| 10 | 41.63 | 31.93 | 31.93 | 31.93 | 28.15 | 31.93 | 41.63 | 31.93 | 41.63 | 41.63 | 41.63 | 31.93 | 41.63 | 41.63 |
| 11 | 40.37 | 30.67 | 30.67 | 30.67 | 26.89 | 30.67 | 40.37 | 30.67 | 40.37 | 40.37 | 40.37 | 30.67 | 40.37 | 40.37 |
| 12 | 39.11 | 29.41 | 29.41 | 29.41 | 25.63 | 29.41 | 39.11 | 29.41 | 39.11 | 39.11 | 39.11 | 29.41 | 39.11 | 39.11 |
| 13 | 37.85 | 28.15 | 28.15 | 28.15 | | 28.15 | 37.85 | 28.15 | 37.85 | 37.85 | 37.85 | 28.15 | 37.85 | 37.85 |
| 14 | 36.59 | 26.89 | 26.89 | 26.89 | | 26.89 | 36.59 | 26.89 | 36.59 | 36.59 | | 26.89 | 36.59 | 36.59 |
| 15 | | 25.63 | 25.63 | 25.63 | | 25.63 | | 25.63 | | | | 25.63 | | |

y-coordinate values for machine locations in dynamic cells in Factory 4

| g | k | | | | | | | | | | | | | |
|---|------|-------|------|-------|-------|------|------|-------|-------|------|-------|------|------|-------|
|   | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| 1 | 0.57 | 8.08 | 0.57 | 14.33 | 14.33 | 0.57 | 5.11 | 12.23 | 18.03 | 5.11 | 12.23 | 5.11 | 0.57 | 18.03 |
| 2 | 0.57 | 8.08 | 0.57 | 14.33 | 14.33 | 0.57 | 5.11 | 12.23 | 18.03 | 5.11 | 12.23 | 5.11 | 0.57 | 18.03 |
| 3 | 0.57 | 8.08 | 0.57 | 14.33 | 14.33 | 0.57 | 5.11 | 12.23 | 18.03 | 5.11 | 12.23 | 5.11 | 0.57 | 18.03 |
| 4 | 0.57 | 8.08 | 0.57 | 14.33 | 14.33 | 0.57 | 5.11 | 12.23 | 18.03 | 5.11 | 12.23 | 5.11 | 0.57 | 18.03 |
| 5 | 0.57 | 8.08 | 0.57 | 14.33 | 14.33 | 0.57 | 5.11 | 12.23 | 18.03 | 5.11 | 12.23 | 5.11 | 0.57 | 18.03 |
| 6 | 0.57 | 8.08 | 0.57 | 14.33 | 14.33 | 0.57 | 5.11 | 12.23 | 18.03 | 5.11 | 12.23 | 5.11 | 0.57 | 18.03 |
| 7 | 1.83 | 8.08 | 0.57 | 14.33 | 14.33 | 0.57 | 6.37 | 13.43 | 19.23 | 5.11 | 13.43 | 6.37 | 1.83 | 19.23 |
| 8 | 2.97 | 9.28 | 1.83 | 14.33 | 14.33 | 1.83 | 7.51 | 14.57 | 20.37 | 6.37 | 14.57 | 7.51 | 2.97 | 20.37 |
| 9 | 4.11 | 10.42 | 2.97 | 15.53 | 15.53 | 2.97 | 8.71 | 16.4 | 22.2 | 7.51 | 16.4 | 8.71 | 4.11 | 22.2 |
| 10 | 4.11 | 11.56 | 4.11 | 16.67 | 16.67 | 4.11 | 8.71 | 16.4 | 22.2 | 8.71 | 16.4 | 8.71 | 4.11 | 22.2 |
| 11 | 4.11 | 12.7 | 4.11 | 17.81 | 17.81 | 4.11 | 8.71 | 16.4 | 22.2 | 8.71 | 16.4 | 8.71 | 4.11 | 22.2 |
| 12 | 4.11 | 13.9 | 4.11 | 19.01 | 19.01 | 4.11 | 8.71 | 16.4 | 22.2 | 8.71 | 16.4 | 8.71 | 4.11 | 22.2 |
| 13 | 4.11 | 13.9 | 4.11 | 19.01 | 19.01 | 4.11 | 8.71 | 16.4 | 22.2 | 8.71 | 16.4 | 8.71 | 4.11 | 22.2 |
| 14 | 4.11 | 13.9 | 4.11 | 19.01 | 19.01 | 4.11 | 8.71 | 16.4 | 22.2 | 8.71 | 16.4 | 8.71 | 4.11 | 22.2 |
| 15 |  | 13.9 | 4.11 | 19.01 | 19.01 | 4.11 |  |  |  | 8.71 |  |  |  |  |
| 16 |  | 13.9 | 4.11 | 19.01 | 19.01 | 4.11 |  |  |  | 8.71 |  |  |  |  |
| 17 |  | 13.9 |  | 19.01 | 19.01 |  |  |  |  |  |  |  |  |  |
| 18 |  | 13.9 |  | 19.01 | 19.01 |  |  |  |  |  |  |  |  |  |

y-coordinate values for machine locations in dynamic cells in Factory 4 continued

| g | k | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| 1 | 0.57 | 0.57 | 7.63 | 14.69 | 22.37 | 0.57 | 17.97 | 7.63 | 6.37 | 12.17 | 0.57 | 14.69 | 6.37 | 12.17 |
| 2 | 0.57 | 0.57 | 7.63 | 14.69 | 22.37 | 0.57 | 17.97 | 7.63 | 6.37 | 12.17 | 0.57 | 14.69 | 6.37 | 12.17 |
| 3 | 0.57 | 0.57 | 7.63 | 14.69 | 22.37 | 0.57 | 17.97 | 7.63 | 6.37 | 12.17 | 0.57 | 14.69 | 6.37 | 12.17 |
| 4 | 0.57 | 0.57 | 7.63 | 14.69 | 22.37 | 0.57 | 17.97 | 7.63 | 6.37 | 12.17 | 0.57 | 14.69 | 6.37 | 12.17 |
| 5 | 0.57 | 0.57 | 7.63 | 14.69 | 22.37 | 0.57 | 17.97 | 7.63 | 6.37 | 12.17 | 0.57 | 14.69 | 6.37 | 12.17 |
| 6 | 0.57 | 0.57 | 7.63 | 14.69 | 23.57 | 0.57 | 17.97 | 7.63 | 6.37 | 12.17 | 0.57 | 14.69 | 6.37 | 12.17 |
| 7 | 1.77 | 1.77 | 8.83 | 15.89 | 24.83 | 1.77 | 19.17 | 8.83 | 7.57 | 13.37 | 1.77 | 15.89 | 7.57 | 13.37 |
| 8 | 3.03 | 3.03 | 10.09 | 17.15 | 27.29 | 3.03 | 20.43 | 10.09 | 8.83 | 14.63 | 3.03 | 17.15 | 8.83 | 14.63 |
| 9 | 4.23 | 4.29 | 11.35 | 18.41 | 27.29 | 4.29 | 22.89 | 11.35 | 10.03 | 15.83 | 4.23 | 18.41 | 10.03 | 15.83 |
| 10 | 4.23 | 5.49 | 12.55 | 19.61 | 27.29 | 5.49 | 22.89 | 12.55 | 10.03 | 15.83 | 4.23 | 19.61 | 10.03 | 15.83 |
| 11 | 4.23 | 5.49 | 12.55 | 19.61 | 27.29 | 5.49 | 22.89 | 12.55 | 10.03 | 15.83 | 4.23 | 19.61 | 10.03 | 15.83 |
| 12 | 4.23 | 5.49 | 12.55 | 19.61 | 27.29 | 5.49 | 22.89 | 12.55 | 10.03 | 15.83 | 4.23 | 19.61 | 10.03 | 15.83 |
| 13 | 4.23 | 5.49 | 12.55 | 19.61 | | 5.49 | 22.89 | 12.55 | 10.03 | 15.83 | 4.23 | 19.61 | 10.03 | 15.83 |
| 14 | 4.23 | 5.49 | 12.55 | 19.61 | | 5.49 | 22.89 | 12.55 | 10.03 | 15.83 | | 19.61 | 10.03 | 15.83 |
| 15 | | 5.49 | 12.55 | 19.61 | | 5.49 | | 12.55 | | | | 19.61 | | |

**Output data of Factory 5**

Number of machines of each machine type in the dynamic cells in Factory 5

| $i$ | $k$ | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 2 | 1 | 1 | 2 | 0 | 2 | 1 | 1 | 2 | 0 | 1 | 0 | 0 |
| 2 | 1 | 0 | 4 | 2 | 1 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 0 | 2 | 2 | 0 | 0 |
| 3 | 0 | 1 | 0 | 0 | 0 | 2 | 2 | 1 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 0 |
| 4 | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 2 | 1 |
| 5 | 0 | 2 | 1 | 0 | 0 | 1 | 0 | 2 | 1 | 1 | 1 | 1 | 0 | 1 | 2 | 0 | 0 | 1 | 1 | 0 | 4 |
| 6 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 2 | 0 | 2 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 2 |
| 7 | 1 | 1 | 2 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 2 | 3 | 2 | 1 | 0 | 1 |
| 8 | 1 | 0 | 0 | 0 | 3 | 2 | 1 | 1 | 3 | 1 | 0 | 0 | 1 | 1 | 2 | 2 | 1 | 0 | 0 | 2 | 0 |
| 9 | 0 | 0 | 0 | 5 | 1 | 0 | 0 | 2 | 3 | 0 | 2 | 0 | 3 | 2 | 0 | 0 | 1 | 1 | 0 | 1 | 0 |
| 10 | 0 | 4 | 0 | 0 | 0 | 0 | 5 | 0 | 3 | 2 | 2 | 1 | 3 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 |
| 11 | 4 | 0 | 3 | 2 | 2 | 1 | 2 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 1 |
| 12 | 0 | 0 | 0 | 1 | 3 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 4 | 0 | 2 | 2 | 0 |
| 13 | 1 | 0 | 0 | 0 | 2 | 2 | 0 | 2 | 1 | 1 | 0 | 4 | 4 | 2 | 1 | 1 | 0 | 0 | 2 | 2 | 0 |
| 14 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 1 | 2 | 0 | 0 | 0 | 4 | 0 | 0 | 3 |
| 15 | 4 | 3 | 4 | 2 | 4 | 3 | 3 | 2 | 5 | 3 | 5 | 3 | 5 | 5 | 7 | 2 | 2 | 3 | 6 | 4 | 3 |

Operator assignment to operations in dynamic cells in Factory 5

| n | k | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 1 | 1 | 1,2 | 1 | 1,2 | 1 | 1,2 | 1,2 | 1,2 | 1,2 | 1 | 1,2 | 1 | 1 | 1 | 1 | 1,2 |
| 2 | 2 | 2 | 1,2 | 3,4 | 2 | 3,4 | 2 | 3 | 3 | 2,3 | 3 | 2 | 2,3 | 2 | 2 | 3 |
| 3 | 3 | 3,4 | 3,4 | 5,6 | 3 | 5 | 3 | 3 | 3 | 4,5 | 3 | 3,4 | 4 | 3 | 3 | 4 |
| 4 | 4 | 5 | 5,6 | 7 | 4 | 6,7 | 4 | 4 | 4 | 6 | 3 | 5,6 | 5 | 4 | 4,5 | 4 |
| 5 | 5 | 6,7 | 7 | 8,9 | 5,6 | 8 | 5 | 5 | 5 | 7 | 4,5 | 7 | 6 | 5 | 6 | 5,6 |
| 6 | 6 | 7 | 8 | 10 | 7 | 8 | 6 | 6 | 5 | 8 | 6 | 8,9 | 7 | 6 | 7 | 7 |
| 7 | 7 | 8,9 | 9 | 11 | 7 | 9 | 6 | 7 | 6,7 | 9 | 7 | 10 | 8,9 | 7 | 8,9 | 8 |
| 8 | 8 | 10 | 10,11 | 12 | 8,9 | 10 | 7 | 8 | 8 | 10 | 8 | 11 | 10 | 8 | 10 | 9,10 |
| 9 | 9 | 11,12 | 12,13 | 13 | 9 | 11 | 7 | 8 | 8 | 11 | 9,10 | 12 | 11,12 | 9 | 11,12 | 11 |
| 10 | 10 | 12 | 14,15 | 13 | 10 | 12,13 | 8,9 | 9 | 8 | 6 | 11,12 | 13,14 | 12 | 10,11 | 13,14 | 12 |
| 11 | 11 | | | 14 | 10 | 13 | 10,11 | 10 | 9 | 12,13 | 13 | 15 | 13 | 12 | 15 | 13 |
| 12 | 11 | | | | 10 | | 12 | 11,12 | 10 | | 14 | 16 | 14 | 13,14 | 16,17 | 14 |
| 13 | 12 | | | | 11 | | 12,13 | 13 | 11 | | | 17,18 | | | | 15 |
| 14 | | | | | 11 | | | 14 | 12 | | | | | | | 16 |
| 15 | | | | | 12 | | | 14 | 13 | | | | | | | |
| 16 | | | | | 13 | | | | 14 | | | | | | | |
| 17 | | | | | 14 | | | | | | | | | | | |
| 18 | | | | | 14 | | | | | | | | | | | |

Operator assignment to operations in dynamic cells in Factory 5 continued

| n | k | | | | |
|---|---|---|---|---|---|
| | 17 | 18 | 19 | 20 | 21 |
| 1 | 1,2 | 1 | 1 | 1 | 1 |
| 2 | 3 | 2 | 2 | 2 | 2 |
| 3 | 4 | 2 | 3 | 3 | 3,4 |
| 4 | 5,6 | 3 | 4 | 4 | 5 |
| 5 | 7 | 4 | 5 | 5 | 6,7 |
| 6 | 8,9 | 4 | 5 | 6 | 8 |
| 7 | 10 | 5 | 6 | 7 | 9 |
| 8 | 11,12 | 6,7 | 7 | 8 | 10 |
| 9 | 12 | 8,9 | 8,9 | 9 | 11 |
| 10 | 13 | 10 | 10 | 9 | 12,13 |
| 11 | 13 | 11 | 11,12 | 10,11 | 14,15 |
| 12 | 14 | 12 | 13 | 12,13 | 15 |
| 13 | | 13,14 | 14,15 | 14 | |
| 14 | | | 13 | 15,16 | |

Coordinates of dynamic cell locations in Factory 5

| k | x | y | k | x | y |
|---|---|---|---|---|---|
| 1 | 15.72 | 9.02 | 12 | 15.72 | 2.93 |
| 2 | 4.71 | 2.34 | 13 | 4.71 | 25.61 |
| 3 | 4.71 | 8.02 | 14 | 4.71 | 19.34 |
| 4 | 4.71 | 2.34 | 15 | 15.72 | 26.79 |
| 5 | 5.3 | 13.88 | 16 | 15.72 | 33.65 |
| 6 | 4.71 | 8.02 | 17 | 15.72 | 2.93 |
| 7 | 15.72 | 8.02 | 18 | 4.71 | 33.06 |
| 8 | 15.72 | 8.02 | 19 | 15.72 | 26.79 |
| 9 | 15.72 | 2.34 | 20 | 15.72 | 33.65 |
| 10 | 15.72 | 9.02 | 21 | 4.71 | 19.34 |
| 11 | 15.72 | 2.34 | | | |

Machine type at each location in Factory 5

| g | k | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 1 | 11 | 5 | 1 | 9 | 1 | 13 | 10 | 6 | 15 | 14 | 10 | 5 | 13 | 15 | 1 | 8 | 12 | 6 | 2 | 3 | 7 |
| 2 | 11 | 5 | 7 | 9 | 15 | 13 | 10 | 6 | 15 | 10 | 10 | 6 | 9 | 1 | 10 | 8 | 12 | 14 | 6 | 4 | 11 |
| 3 | 11 | 7 | 7 | 9 | 8 | 2 | 6 | 8 | 13 | 10 | 3 | 13 | 9 | 6 | 7 | 11 | 6 | 5 | 7 | 8 | 5 |
| 4 | 8 | 10 | 2 | 9 | 6 | 2 | 10 | 9 | 8 | 6 | 7 | 13 | 10 | 1 | 15 | 2 | 8 | 4 | 12 | 10 | 5 |
| 5 | 14 | 10 | 2 | 2 | 8 | 7 | 10 | 13 | 8 | 6 | 3 | 4 | 8 | 13 | 15 | 1 | 1 | 3 | 1 | 6 | 4 |
| 6 | 11 | 3 | 11 | 2 | 8 | 8 | 10 | 7 | 8 | 13 | 15 | 4 | 13 | 13 | 6 | 2 | 1 | 7 | 12 | 8 | 6 |
| 7 | 15 | 4 | 11 | 1 | 12 | 8 | 11 | 1 | 1 | 1 | 15 | 11 | 13 | 15 | 13 | 2 | 4 | 14 | 2 | 4 | 6 |
| 8 | 15 | 4 | 11 | 11 | 4 | 3 | 8 | 12 | 10 | 14 | 11 | 1 | 15 | 5 | 8 | 12 | 11 | 14 | 15 | 3 | 14 |
| 9 | 7 | 14 | 14 | 11 | 11 | 3 | 12 | 13 | 10 | 8 | 1 | 1 | 15 | 8 | 8 | 4 | 11 | 14 | 13 | 9 | 14 |
| 10 | 13 | 10 | 5 | 12 | 11 | 2 | 11 | 12 | 9 | 11 | 5 | 10 | 14 | 9 | 15 | 12 | 7 | 2 | 13 | 15 | 5 |
| 11 | 2 | 10 | 2 | 7 | 12 | 11 | 2 | 3 | 5 | 5 | 14 | 3 | 10 | 9 | 2 | 12 | 12 | 2 | 5 | 13 | 5 |
| 12 | 15 | 1 | 2 | 9 | 13 | 5 | 2 | 9 | 9 | 15 | 14 | 3 | 10 | 15 | 2 | 13 | 12 | 9 | 15 | 13 | 15 |
| 13 | 15 | 15 | 15 | 6 | 2 | 15 | 3 | 5 | 10 | 15 | 9 | 13 | 9 | 15 | 5 | 7 | 9 | 7 | 15 | 12 | 15 |
| 14 | | 15 | 15 | 15 | 13 | 15 | 3 | 5 | 9 | 15 | 9 | 13 | 15 | 15 | 5 | 11 | 7 | 15 | 10 | 12 | 15 |
| 15 | | 15 | 15 | 15 | 7 | 15 | 15 | 11 | 15 | | 15 | 13 | 15 | | 15 | 7 | 7 | 15 | 15 | 15 | |
| 16 | | | 15 | | 12 | | 15 | 15 | 1 | | 15 | 15 | | | 15 | 15 | 15 | 15 | 15 | 15 | |
| 17 | | | | | 15 | | 15 | 15 | 15 | | 15 | 15 | | | 15 | 15 | 15 | | 15 | 15 | |
| 18 | | | | | 9 | | | | 15 | | | 15 | | | | | | | | | |
| 19 | | | | | 15 | | | | | | | | | | | | | | | | |
| 20 | | | | | 15 | | | | | | | | | | | | | | | | |

x-coordinate values for machine locations in dynamic cells in Factory 5

| g | k | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 1 | 12.19 | 0.59 | 0.59 | 0.59 | 0.59 | 0.59 | 11.01 | 11.01 | 11.01 | 12.19 | 11.01 |
| 2 | 13.37 | 1.77 | 1.77 | 1.77 | 1.77 | 1.77 | 12.19 | 12.19 | 12.19 | 13.37 | 12.19 |
| 3 | 14.55 | 2.95 | 2.95 | 2.95 | 2.95 | 2.95 | 13.37 | 13.37 | 13.37 | 14.55 | 13.37 |
| 4 | 15.73 | 4.13 | 4.13 | 4.13 | 4.13 | 4.13 | 14.55 | 14.55 | 14.55 | 15.73 | 14.55 |
| 5 | 16.91 | 5.31 | 5.31 | 5.31 | 5.31 | 5.31 | 15.73 | 15.73 | 15.73 | 16.91 | 15.73 |
| 6 | 18.09 | 6.49 | 6.49 | 6.49 | 6.49 | 6.49 | 16.91 | 16.91 | 16.91 | 18.09 | 16.91 |
| 7 | 20.44 | 7.67 | 7.67 | 7.67 | 7.67 | 7.67 | 18.09 | 18.09 | 18.09 | 20.44 | 18.09 |
| 8 | 20.44 | 10.02 | 10.02 | 10.02 | 8.85 | 10.02 | 19.27 | 19.27 | 19.27 | 20.44 | 19.27 |
| 9 | 18.09 | 10.02 | 10.02 | 10.02 | 11.2 | 10.02 | 11.20 | 11.20 | 11.20 | 18.09 | 11.20 |
| 10 | 16.91 | 7.67 | 7.67 | 7.67 | 11.2 | 7.67 | 11.20 | 11.20 | 11.20 | 16.91 | 11.20 |
| 11 | 15.73 | 6.49 | 6.49 | 6.49 | 11.2 | 6.49 | 19.27 | 19.27 | 19.27 | 15.73 | 19.27 |
| 12 | 14.55 | 5.31 | 5.31 | 5.31 | 11.2 | 5.31 | 18.09 | 18.09 | 18.09 | 14.55 | 18.09 |
| 13 | 13.37 | 4.13 | 4.13 | 4.13 | 8.85 | 4.13 | 16.91 | 16.91 | 16.91 | 13.37 | 16.91 |
| 14 | | 2.95 | 2.95 | 2.95 | 7.67 | 2.95 | 15.73 | 15.73 | 15.73 | 12.19 | 15.73 |
| 15 | | 1.77 | 1.77 | 1.77 | 6.49 | 1.77 | 14.55 | 14.55 | 14.55 | | 14.55 |
| 16 | | | 1.77 | | 5.31 | | 13.37 | 13.37 | 13.37 | | 13.37 |
| 17 | | | | | 4.13 | | 12.19 | 12.19 | 12.19 | | 12.19 |
| 18 | | | | | 2.95 | | | | 11 | | |
| 19 | | | | | 1.77 | | | | | | |
| 20 | | | | | 0.59 | | | | | | |

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x-coordinate values for machine locations in dynamic cells in Factory 5 continued

| g | k | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 1 | 11.01 | 0.59 | 0.59 | 11.01 | 11.01 | 11.01 | 0.59 | 11.01 | 11.01 | 0.59 |
| 2 | 12.19 | 1.77 | 1.77 | 12.19 | 12.19 | 12.19 | 1.77 | 12.19 | 12.19 | 1.77 |
| 3 | 13.37 | 2.95 | 2.95 | 13.37 | 13.37 | 13.37 | 2.95 | 13.37 | 13.37 | 2.95 |
| 4 | 14.55 | 4.13 | 4.13 | 14.55 | 14.55 | 14.55 | 4.13 | 14.55 | 14.55 | 4.13 |
| 5 | 15.73 | 5.31 | 5.31 | 15.73 | 15.73 | 15.73 | 5.31 | 15.73 | 15.73 | 5.31 |
| 6 | 16.91 | 6.49 | 6.49 | 16.91 | 16.91 | 16.91 | 6.49 | 16.91 | 16.91 | 6.49 |
| 7 | 18.09 | 8.84 | 8.84 | 18.09 | 18.09 | 18.09 | 8.84 | 18.09 | 18.09 | 8.84 |
| 8 | 20.44 | 8.84 | 8.84 | 20.44 | 20.44 | 20.44 | 8.84 | 20.44 | 20.44 | 8.84 |
| 9 | 20.44 | 8.84 | 6.49 | 20.44 | 20.44 | 20.44 | 8.84 | 20.44 | 20.44 | 6.49 |
| 10 | 20.44 | 8.84 | 5.31 | 20.44 | 20.44 | 20.44 | 8.84 | 20.44 | 20.44 | 5.31 |
| 11 | 18.09 | 6.49 | 4.13 | 18.09 | 18.09 | 18.09 | 8.84 | 18.09 | 18.09 | 4.13 |
| 12 | 16.91 | 5.31 | 2.95 | 16.91 | 16.91 | 16.91 | 8.84 | 16.91 | 16.91 | 2.95 |
| 13 | 15.73 | 4.13 | 1.77 | 15.73 | 15.73 | 15.73 | 6.49 | 15.73 | 15.73 | 1.77 |
| 14 | 14.55 | 2.95 | 0.59 | 14.55 | 14.55 | 14.55 | 5.31 | 14.55 | 14.55 | 0.59 |
| 15 | 13.37 | 1.77 | | 13.37 | 13.37 | 13.37 | 4.13 | 13.37 | 13.37 | |
| 16 | 12.19 | | | 12.19 | 12.19 | 12.19 | 2.95 | 12.19 | 12.19 | |
| 17 | 11.01 | | | 11.01 | 11.01 | 11.01 | | 11.01 | 11.01 | |

y-coordinate values for machine locations in dynamic cells in Factory 5

| g | k | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 1 | 11.94 | 0.58 | 6.26 | 0.58 | 11.94 | 6.26 | 6.26 | 6.26 | 0.58 | 11.94 | 0.58 |
| 2 | 11.94 | 0.58 | 6.26 | 0.58 | 11.94 | 6.26 | 6.26 | 6.26 | 0.58 | 11.94 | 0.58 |
| 3 | 11.94 | 0.58 | 6.26 | 0.58 | 11.94 | 6.26 | 6.26 | 6.26 | 0.58 | 11.94 | 0.58 |
| 4 | 11.94 | 0.58 | 6.26 | 0.58 | 11.94 | 6.26 | 6.26 | 6.26 | 0.58 | 11.94 | 0.58 |
| 5 | 11.94 | 0.58 | 6.26 | 0.58 | 11.94 | 6.26 | 6.26 | 6.26 | 0.58 | 11.94 | 0.58 |
| 6 | 11.94 | 0.58 | 6.26 | 0.58 | 11.94 | 6.26 | 6.26 | 6.26 | 0.58 | 11.94 | 0.58 |
| 7 | 13.11 | 0.58 | 6.26 | 0.58 | 11.94 | 6.26 | 6.26 | 6.26 | 0.58 | 13.11 | 0.58 |
| 8 | 14.29 | 1.75 | 7.43 | 1.75 | 11.94 | 7.43 | 6.26 | 6.26 | 0.58 | 14.29 | 0.58 |
| 9 | 15.46 | 2.93 | 8.61 | 2.93 | 13.1 | 8.61 | 7.43 | 7.43 | 1.75 | 15.46 | 1.75 |
| 10 | 15.46 | 4.10 | 9.78 | 4.10 | 14.3 | 9.78 | 8.61 | 8.61 | 2.93 | 15.46 | 2.93 |
| 11 | 15.46 | 4.10 | 9.78 | 4.10 | 15.5 | 9.78 | 9.78 | 9.78 | 4.10 | 15.46 | 4.10 |
| 12 | 15.46 | 4.10 | 9.78 | 4.10 | 16.7 | 9.78 | 9.78 | 9.78 | 4.10 | 15.46 | 4.10 |
| 13 | 15.46 | 4.10 | 9.78 | 4.10 | 15.46 | 9.78 | 9.78 | 9.78 | 4.10 | 15.46 | 4.10 |
| 14 | | 4.10 | 9.78 | 4.10 | 15.46 | 9.78 | 9.78 | 9.78 | 4.10 | 15.46 | 4.10 |
| 15 | | 4.10 | 9.78 | 4.10 | 15.46 | 9.78 | 9.78 | 9.78 | 4.10 | | 4.10 |
| 16 | | | 9.78 | | 15.46 | | 9.78 | 9.78 | 4.10 | | 4.10 |
| 17 | | | | | 15.46 | | 9.78 | 9.78 | 4.10 | | 4.10 |
| 18 | | | | | 15.46 | | | | 4.10 | | |
| 19 | | | | | 15.46 | | | | | | |
| 20 | | | | | 15.46 | | | | | | |

y-coordinate values for machine locations in dynamic cells in Factory 5 continued

| g | k | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
|   | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 1 | 17.58 | 23.25 | 17.58 | 24.26 | 31.30 | 17.58 | 30.12 | 24.26 | 31.30 | 17.58 |
| 2 | 17.58 | 23.25 | 17.58 | 24.26 | 31.30 | 17.58 | 30.12 | 24.26 | 31.30 | 17.58 |
| 3 | 17.58 | 23.25 | 17.58 | 24.26 | 31.30 | 17.58 | 30.12 | 24.26 | 31.30 | 17.58 |
| 4 | 17.58 | 23.25 | 17.58 | 24.26 | 31.30 | 17.58 | 30.12 | 24.26 | 31.30 | 17.58 |
| 5 | 17.58 | 23.25 | 17.58 | 24.26 | 31.30 | 17.58 | 30.12 | 24.26 | 31.30 | 17.58 |
| 6 | 17.58 | 23.25 | 17.58 | 24.26 | 31.30 | 17.58 | 30.12 | 24.26 | 31.30 | 17.58 |
| 7 | 17.58 | 24.43 | 18.75 | 24.26 | 31.30 | 17.58 | 31.29 | 24.26 | 31.30 | 18.75 |
| 8 | 18.75 | 25.61 | 19.93 | 25.43 | 32.47 | 18.75 | 32.47 | 25.43 | 32.47 | 19.93 |
| 9 | 19.93 | 26.79 | 21.10 | 26.61 | 33.65 | 19.93 | 33.65 | 26.61 | 33.65 | 21.10 |
| 10 | 21.11 | 27.96 | 21.10 | 27.79 | 34.83 | 21.11 | 34.83 | 27.79 | 34.83 | 21.10 |
| 11 | 22.28 | 27.96 | 21.10 | 28.96 | 36.00 | 22.28 | 36.00 | 28.96 | 36.00 | 21.10 |
| 12 | 22.28 | 27.96 | 21.10 | 28.96 | 36.00 | 22.28 | 36.00 | 28.96 | 36.00 | 21.10 |
| 13 | 22.28 | 27.96 | 21.10 | 28.96 | 36.00 | 22.28 | 36.00 | 28.96 | 36.00 | 21.10 |
| 14 | 22.28 | 27.96 | 21.10 | 28.96 | 36.00 | 22.28 | 36.00 | 28.96 | 36.00 | 21.10 |
| 15 | 22.28 | 27.96 |   | 28.96 | 36.00 | 22.28 | 36.00 | 28.96 | 36.00 |   |
| 16 | 22.28 |   |   | 28.96 | 36.00 | 22.28 | 36.00 | 28.96 | 36.00 |   |
| 17 | 22.28 |   |   | 28.96 | 36.00 | 22.28 |   | 28.96 | 36.00 |   |

**Output data of Factory 6**

Number of machines of each machine type in the dynamic cells in Factory 6

| $i$ | $k$ | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 1 | 1 | 0 | 1 | 0 | 1 | 1 | 2 | 2 | 0 | 1 | 0 | 0 | 2 | 2 | 1 | 1 | 1 | 2 | 0 | 0 | 1 |
| 2 | 2 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 1 | 0 | 0 | 4 |
| 3 | 2 | 0 | 2 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 1 | 0 | 0 | 1 | 0 | 1 |
| 4 | 1 | 2 | 1 | 2 | 1 | 2 | 0 | 0 | 1 | 3 | 1 | 1 | 1 | 0 | 1 | 3 | 0 | 2 | 0 | 4 | 1 |
| 5 | 1 | 1 | 1 | 2 | 1 | 2 | 0 | 1 | 2 | 1 | 1 | 0 | 0 | 2 | 1 | 1 | 1 | 0 | 1 | 0 | 0 |
| 6 | 1 | 0 | 0 | 1 | 0 | 2 | 0 | 4 | 0 | 1 | 1 | 2 | 0 | 3 | 1 | 0 | 2 | 0 | 1 | 0 | 0 |
| 7 | 1 | 2 | 0 | 1 | 0 | 0 | 3 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 2 | 0 | 2 | 1 | 1 | 4 | 1 |
| 8 | 0 | 0 | 1 | 0 | 1 | 0 | 2 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 3 | 0 | 0 | 2 |
| 9 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 3 | 1 | 2 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 2 | 1 | 0 |
| 10 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 2 | 1 | 1 | 0 | 0 | 2 | 0 | 1 | 2 | 2 | 0 |
| 11 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 0 | 0 | 0 | 3 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 3 | 0 | 0 |
| 12 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 3 | 1 | 2 | 1 | 0 | 2 | 1 | 0 | 0 | 1 |
| 13 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 2 | 4 | 0 | 2 | 0 | 0 |
| 14 | 0 | 2 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 2 | 2 | 0 | 1 | 0 | 0 | 0 | 1 | 2 |
| 15 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 2 | 1 | 3 | 0 | 0 | 3 | 1 | 2 | 0 |
| 16 | 3 | 3 | 2 | 3 | 4 | 2 | 2 | 2 | 3 | 3 | 3 | 2 | 2 | 4 | 2 | 4 | 2 | 3 | 3 | 3 | 2 |

Operator assignment to operations in dynamic cells in Factory 6

| n | k | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1,2 | 1 | 1 |
| 2 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2,3 | 2 | 2 | 2 | 2,3 | 3 | 2,3 | 2 |
| 3 | 2 | 3 | 3 | 2 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 3 | 4,5 | 2 | 3 | 3 | 4 | 4 | 4 | 3,4 |
| 4 | 3 | 4 | 3 | 2 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 4 | 6 | 3 | 4 | 4 | 5 | 5,6 | 5 | 5 |
| 5 | 4 | 4 | 4 | 3 | 4 | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 5 | 7 | 4 | 5 | 5 | 6 | 7 | 6 | 6 |
| 6 | 4 | 5 | 4 | 3 | 5 | 3 | 4 | 2 | 3 | 3 | 3 | 2 | 5 | 7 | 5 | 5 | 6,7 | 7 | 7 | 7 | 7 |
| 7 | 5 | 6 | 5 | 4 | 6 | 3 | 4 | 3 | 3 | 3 | 3 | 3 | 5 | 7 | 6 | 6 | 8 | 8 | 8 | 8,9 | 8 |
| 8 | 6 | 7 | 5 | 4 | 6 | 4 | 5 | 3 | 3 | 3 | 4 | 3 | 6 | 8 | 7 | 7 | 9 | 9,10 | 9,10 | 10 | 9,10 |
| 9 | 7 | 8 | 6 | 4 | 7 | 4 | 5 | 4 | 4 | 4 | 4 | 4 | 7 | 9 | 8 | 8 | 10 | 11 | 11 | 11 | 11 |
| 10 | 8 | 7 | 6 | 5 | 7 | 4 | 6 | 4 | 4 | 4 | 4 | 4 | 8 | 9 | 8 | 9 | 11 | 5 | 12 | 12 | 11 |
| 11 | 9 | 7 | 7 | 5 | 8 | 5 | 6 | 5 | 4 | 4 | 5 | 5 | 9 | 9 | 9 | 9 | 12 | 12 | 13 | 13,14 | 11 |
| 12 | 10 | 9 | 7 | 6 | 8 | 5 |  | 5 | 5 | 5 | 5 | 5 | 10 | 10 | 10 | 10 | 13 | 13 | 14 | 15 | 12 |
| 13 | 11 | 10 | 8 | 6 | 9 | 6 |  | 5 |  | 5 | 5 | 5 | 10 | 11 | 11 | 11 | 13 | 14 | 15,16 | 15 | 13 |
| 14 | 11 | 10 | 8 | 6 | 9 | 6 |  | 6 |  | 5 | 6 |  | 7 | 12 | 12 | 12 | 14 | 14 |  | 16 |  |
| 15 | 12 |  | 9 | 7 | 10 | 7 |  |  |  |  | 6 |  | 11 | 13 | 13 | 13 | 14 | 15 |  |  |  |
| 16 | 13 |  |  | 7 | 10 | 7 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

Coordinates of dynamic cell locations in Factory 6

| $k$ | x | y | $k$ | x | y |
|---|---|---|---|---|---|
| 1 | 5.5 | 2.25 | 12 | 16.88 | 7.75 |
| 2 | 16.88 | 2.25 | 13 | 17.5 | 17.25 |
| 3 | 5.5 | 7.75 | 14 | 2.2 | 17.875 |
| 4 | 5.5 | 13.25 | 15 | 17.5 | 24.75 |
| 5 | 5.5 | 7.75 | 16 | 17.5 | 17.25 |
| 6 | 5.5 | 2.25 | 17 | 2.2 | 24.625 |
| 7 | 16.25 | 13.25 | 18 | 2.2 | 17.875 |
| 8 | 16.88 | 7.75 | 19 | 2.2 | 24.625 |
| 9 | 16.25 | 13.25 | 20 | 2.2 | 31.375 |
| 10 | 16.88 | 2.25 | 21 | 17.5 | 24.75 |

Machine type at each location in Factory 6

| g | k | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|   | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 1 | 1 | 14 | 14 | 2 | 3 | 14 | 14 | 6 | 10 | 4 | 14 | 12 | 1 | 13 | 7 | 13 | 12 | 1 | 11 | 16 | 1 |
| 2 | 2 | 10 | 5 | 5 | 5 | 6 | 3 | 3 | 5 | 15 | 6 | 4 | 14 | 5 | 3 | 4 | 5 | 15 | 11 | 4 | 8 |
| 3 | 2 | 9 | 2 | 5 | 2 | 6 | 1 | 10 | 15 | 6 | 4 | 6 | 9 | 5 | 8 | 13 | 7 | 15 | 15 | 4 | 14 |
| 4 | 5 | 4 | 3 | 7 | 10 | 2 | 8 | 7 | 16 | 12 | 9 | 14 | 11 | 6 | 11 | 11 | 2 | 16 | 7 | 15 | 14 |
| 5 | 7 | 7 | 3 | 4 | 8 | 13 | 7 | 6 | 9 | 9 | 9 | 6 | 15 | 6 | 1 | 10 | 7 | 15 | 9 | 14 | 7 |
| 6 | 11 | 14 | 4 | 4 | 16 | 5 | 1 | 6 | 14 | 13 | 11 | 8 | 8 | 1 | 7 | 1 | 13 | 2 | 9 | 9 | 4 |
| 7 | 6 | 7 | 8 | 16 | 16 | 10 | 11 | 6 | 4 | 5 | 16 | 9 | 10 | 12 | 15 | 5 | 13 | 4 | 3 | 7 | 3 |
| 8 | 12 | 11 | 10 | 11 | 9 | 5 | 7 | 12 | 5 | 16 | 12 | 12 | 15 | 15 | 3 | 14 | 2 | 12 | 10 | 10 | 12 |
| 9 | 16 | 4 | 2 | 11 | 1 | 1 | 8 | 1 | 9 | 1 | 11 | 3 | 3 | 6 | 12 | 2 | 1 | 8 | 6 | 10 | 2 |
| 10 | 3 | 5 | 11 | 12 | 11 | 3 | 16 | 1 | 13 | 4 | 11 | 10 | 7 | 1 | 5 | 10 | 13 | 8 | 13 | 7 | 2 |
| 11 | 3 | 16 | 9 | 9 | 4 | 4 | 16 | 5 | 16 | 4 | 10 | 13 | 14 | 16 | 15 | 4 | 6 | 10 | 13 | 4 | 2 |
| 12 | 4 | 15 | 13 | 6 | 12 | 4 |  | 16 | 16 | 8 | 10 | 16 | 4 | 12 | 6 | 4 | 9 | 8 | 5 | 15 | 8 |
| 13 | 10 | 16 | 1 | 3 | 11 | 11 |  | 16 |  | 16 | 5 | 16 | 12 | 16 | 4 | 16 | 6 | 16 | 10 | 7 | 2 |
| 14 | 15 | 16 | 16 | 10 | 13 | 12 |  |  |  | 16 | 7 |  | 1 | 3 | 16 | 3 | 12 | 4 | 11 | 7 | 16 |
| 15 | 16 |  | 16 | 16 | 16 | 16 |  |  |  |  | 16 |  | 16 | 14 | 16 | 16 | 13 | 1 | 16 | 4 | 16 |
| 16 | 16 |  |  | 16 | 16 | 16 |  |  |  |  |  |  |  | 16 | 16 |  | 16 | 7 | 16 | 16 |  |
| 17 |  |  |  |  |  |  |  |  |  |  |  |  |  | 16 |  |  | 16 | 16 | 16 | 16 |  |
| 18 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 16 |  |  |

x-coordinate values for machine locations in dynamic cells in Factory 6

| g | k | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 1 | 0.63 | 12.63 | 0.63 | 0.63 | 0.63 | 0.63 | 12.63 | 12.63 | 12.63 | 12.63 | 0.63 | 12.63 |
| 2 | 1.88 | 13.88 | 1.88 | 1.88 | 1.88 | 1.88 | 13.88 | 13.88 | 13.88 | 13.88 | 1.88 | 13.88 |
| 3 | 3.13 | 15.13 | 3.13 | 3.13 | 3.13 | 3.13 | 15.13 | 15.13 | 15.13 | 15.13 | 3.13 | 15.13 |
| 4 | 4.38 | 16.38 | 4.38 | 4.38 | 4.38 | 4.38 | 16.38 | 16.38 | 16.38 | 16.38 | 4.38 | 16.38 |
| 5 | 5.63 | 17.63 | 5.63 | 5.63 | 5.63 | 5.63 | 17.63 | 17.63 | 17.63 | 17.63 | 5.63 | 17.63 |
| 6 | 6.88 | 18.88 | 6.88 | 6.88 | 6.88 | 6.88 | 20.00 | 18.88 | 20.00 | 18.88 | 6.88 | 18.88 |
| 7 | 8.13 | 20.00 | 8.13 | 8.13 | 8.13 | 8.13 | 20.00 | 20.00 | 20.00 | 20.00 | 8.13 | 20.00 |
| 8 | 10.50 | 20.00 | 10.50 | 10.50 | 10.50 | 10.50 | 17.63 | 20.00 | 17.63 | 20.00 | 10.50 | 20.00 |
| 9 | 10.50 | 18.88 | 10.50 | 10.50 | 10.50 | 10.50 | 16.38 | 18.88 | 16.38 | 18.88 | 10.50 | 18.88 |
| 10 | 8.13 | 17.63 | 8.13 | 8.13 | 8.13 | 8.13 | 15.13 | 17.63 | 15.13 | 17.63 | 8.13 | 17.63 |
| 11 | 6.88 | 16.38 | 6.88 | 6.88 | 6.88 | 6.88 | 13.88 | 16.38 | 13.88 | 16.38 | 6.88 | 16.38 |
| 12 | 5.63 | 15.13 | 5.63 | 5.63 | 5.63 | 5.63 |  | 15.13 | 12.63 | 15.13 | 5.63 | 15.13 |
| 13 | 4.38 | 13.88 | 4.38 | 4.38 | 4.38 | 4.38 |  | 13.88 |  | 13.88 | 4.38 | 13.88 |
| 14 | 3.13 | 12.63 | 3.13 | 3.13 | 3.13 | 3.13 |  |  |  | 12.63 | 3.13 |  |
| 15 | 1.88 |  | 1.88 | 1.88 | 1.88 | 1.88 |  |  |  |  | 1.88 |  |
| 16 | 0.63 |  |  | 0.63 | 0.63 | 0.63 |  |  |  |  |  |  |

x-coordinate values for machine locations in dynamic cells in Factory 6 continued

| g | k | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 1 | 12.63 | 0.63 | 12.63 | 12.63 | 0.63 | 0.63 | 0.63 | 0.63 | 12.63 |
| 2 | 13.88 | 1.88 | 13.88 | 13.88 | 1.88 | 1.88 | 1.88 | 1.88 | 13.88 |
| 3 | 15.13 | 3.13 | 15.13 | 15.13 | 3.13 | 3.13 | 3.13 | 3.13 | 15.13 |
| 4 | 16.38 | 4.38 | 16.38 | 16.38 | 4.38 | 4.38 | 4.38 | 4.38 | 16.38 |
| 5 | 17.63 | 5.63 | 17.63 | 17.63 | 5.63 | 5.63 | 5.63 | 5.63 | 17.63 |
| 6 | 18.88 | 6.88 | 18.88 | 18.88 | 6.88 | 6.88 | 6.88 | 6.88 | 18.88 |
| 7 | 20.13 | 8.13 | 20.13 | 20.13 | 8.13 | 8.13 | 8.13 | 8.13 | 20.13 |
| 8 | 22.50 | 10.50 | 22.50 | 22.50 | 10.50 | 10.50 | 10.50 | 10.50 | 22.50 |
| 9 | 22.50 | 10.50 | 22.50 | 22.50 | 10.50 | 10.50 | 10.50 | 10.50 | 22.50 |
| 10 | 20.13 | 10.50 | 20.13 | 20.13 | 10.50 | 10.50 | 10.50 | 10.50 | 20.13 |
| 11 | 18.88 | 8.13 | 18.88 | 18.88 | 8.13 | 8.13 | 8.13 | 8.13 | 18.88 |
| 12 | 17.63 | 6.88 | 17.63 | 17.63 | 6.88 | 6.88 | 6.88 | 6.88 | 17.63 |
| 13 | 16.38 | 5.63 | 16.38 | 16.38 | 5.63 | 5.63 | 5.63 | 5.63 | 16.38 |
| 14 | 15.13 | 4.38 | 15.13 | 15.13 | 4.38 | 4.38 | 4.38 | 4.38 | 15.13 |
| 15 | 13.88 | 3.13 | 13.88 | 13.88 | 3.13 | 3.13 | 3.13 | 3.13 | 13.88 |
| 16 | 12.63 | 1.88 | | 12.63 | 1.88 | 1.88 | 1.88 | 1.88 | |
| 17 | | 0.63 | | | 0.63 | 0.63 | 0.63 | 0.63 | |

y-coordinate values for machine locations in dynamic cells in Factory 6

| g | k | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 1 | 0.50 | 0.50 | 6.00 | 11.50 | 6.00 | 0.50 | 11.50 | 6.00 | 11.50 | 0.50 | 11.50 | 6.00 |
| 2 | 0.50 | 0.50 | 6.00 | 11.50 | 6.00 | 0.50 | 11.50 | 6.00 | 11.50 | 0.50 | 11.50 | 6.00 |
| 3 | 0.50 | 0.50 | 6.00 | 11.50 | 6.00 | 0.50 | 11.50 | 6.00 | 11.50 | 0.50 | 11.50 | 6.00 |
| 4 | 0.50 | 0.50 | 6.00 | 11.50 | 6.00 | 0.50 | 11.50 | 6.00 | 11.50 | 0.50 | 11.50 | 6.00 |
| 5 | 0.50 | 0.50 | 6.00 | 11.50 | 6.00 | 0.50 | 11.50 | 6.00 | 11.50 | 0.50 | 11.50 | 6.00 |
| 6 | 0.50 | 0.50 | 6.00 | 11.50 | 6.00 | 0.50 | 12.63 | 6.00 | 12.63 | 0.50 | 11.50 | 6.00 |
| 7 | 0.50 | 1.63 | 6.00 | 11.50 | 6.00 | 0.50 | 13.87 | 9.50 | 13.87 | 1.63 | 11.50 | 9.50 |
| 8 | 1.63 | 2.88 | 9.50 | 12.63 | 9.50 | 1.63 | 15.00 | 10.75 | 15.00 | 2.88 | 12.63 | 10.75 |
| 9 | 2.88 | 4.00 | 10.75 | 13.88 | 10.75 | 2.88 | 15.00 | 9.50 | 15.00 | 4.00 | 13.88 | 9.50 |
| 10 | 4.00 | 4.00 | 9.50 | 15.00 | 9.50 | 4.00 | 15.00 | 9.50 | 15.00 | 4.00 | 15.00 | 9.50 |
| 11 | 4.00 | 4.00 | 9.50 | 15.00 | 9.50 | 4.00 | 15.00 | 9.50 | 15.00 | 4.00 | 15.00 | 9.50 |
| 12 | 4.00 | 4.00 | 9.50 | 15.00 | 9.50 | 4.00 | | 9.50 | 15.00 | 4.00 | 15.00 | 9.50 |
| 13 | 4.00 | 4.00 | 9.50 | 15.00 | 9.50 | 4.00 | | 9.50 | | 4.00 | 15.00 | 9.50 |
| 14 | 4.00 | 4.00 | 9.50 | 15.00 | 9.50 | 4.00 | | | | 4.00 | 15.00 | |
| 15 | 4.00 | | 9.50 | 15.00 | 9.50 | 4.00 | | | | | 15.00 | |
| 16 | 4.00 | | | 15.00 | 6.00 | 4.00 | | | | | 15.00 | |

y-coordinate values for machine locations in dynamic cells in Factory 6 continued

| g | k | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
| 1 | 15.63 | 15.50 | 21.13 | 15.63 | 22.38 | 15.50 | 22.38 | 29.13 | 21.13 |
| 2 | 15.63 | 15.50 | 21.13 | 15.63 | 22.38 | 15.50 | 22.38 | 29.13 | 21.13 |
| 3 | 15.63 | 15.50 | 21.13 | 15.63 | 22.38 | 15.50 | 22.38 | 29.13 | 21.13 |
| 4 | 15.63 | 15.50 | 21.13 | 15.63 | 22.38 | 15.50 | 22.38 | 29.13 | 21.13 |
| 5 | 15.63 | 15.50 | 21.13 | 15.63 | 22.38 | 15.50 | 22.38 | 29.13 | 21.13 |
| 6 | 15.63 | 15.50 | 21.13 | 15.63 | 22.38 | 15.50 | 22.38 | 29.13 | 21.13 |
| 7 | 15.63 | 15.50 | 21.13 | 15.63 | 22.38 | 15.50 | 22.38 | 29.13 | 21.13 |
| 8 | 16.63 | 16.63 | 22.13 | 16.63 | 23.38 | 16.63 | 23.38 | 30.13 | 22.13 |
| 9 | 17.88 | 17.88 | 23.38 | 17.88 | 24.63 | 17.88 | 24.63 | 31.38 | 23.38 |
| 10 | 19.00 | 19.13 | 23.50 | 19.00 | 25.88 | 19.13 | 25.88 | 32.63 | 23.50 |
| 11 | 19.00 | 20.25 | 23.50 | 19.00 | 27.00 | 20.25 | 27.00 | 33.75 | 23.50 |
| 12 | 19.00 | 20.25 | 23.50 | 19.00 | 27.00 | 20.25 | 27.00 | 33.75 | 23.50 |
| 13 | 19.00 | 20.25 | 23.50 | 19.00 | 27.00 | 20.25 | 27.00 | 33.75 | 23.50 |
| 14 | 19.00 | 20.25 | 23.50 | 19.00 | 27.00 | 20.25 | 27.00 | 33.75 | 23.50 |
| 15 | 19.00 | 20.25 | 23.50 | 19.00 | 27.00 | 20.25 | 27.00 | 33.75 | 23.50 |
| 16 | 19.00 | 20.25 | | 19.00 | 27.00 | 20.25 | 27.00 | 33.75 | |
| 17 | | 20.25 | | | 27.00 | 20.25 | 27.00 | 33.75 | |